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FEASIBILITY STUDY REPORT

STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS
CERCLA DOCKET NO. 06-02-06

Prepared for:

Chevron Environmental Management Company and
Huntsman Petrochemical LLC

APRIL 2012
REF. NO. 027545-00 (19)

EXECUTIVE SUMMARY

Conestoga-Rovers & Associates (CRA) and Cardno ENTRIX, on behalf of Chevron Environmental Management Company (CEMC) and Huntsman Petrochemical LLC (Huntsman), submit herein to the United States Environmental Protection Agency (EPA) the Draft Feasibility Study (FS) Report for the Star Lake Canal Superfund Site (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Docket No. 06-02-06) located in Jefferson County, Texas (Site). The EPA entered into an Administrative Settlement Agreement and Order on Consent (AOC) for Remedial Investigation/Feasibility Study (RI/FS) with CEMC and Huntsman for the Site on December 22, 2005. The AOC required that a RI/FS be completed for the Site in accordance with relevant EPA Guidance documents. This submittal is intended for use as the basis for the Record of Decision expected subsequently.

The location of the Site is shown on the vicinity map included as Figure 1-1 and an aerial photograph included as Figure 1-2. The Site includes the two industrial canals (Star Lake Canal and Jefferson Canal) and the adjacent wetlands. Molasses Bayou is located southeast of the Star Lake Canal and intersects the canal at two locations. Gulf States Utility Canal is a canal that was excavated during the placement of a utility line and is located approximately 100 feet northwest of Star Lake Canal. Gulf States Utility Canal extends parallel to Star Lake Canal from northeast of Atlantic Road to the Neches River. Star Lake Canal and Jefferson Canal are used by nearby industries for permitted discharge of industrial effluents. Historical unpermitted and permitted discharges have resulted in the deposition of potentially hazardous constituents at the Site.

Industrial operations have occurred in areas surrounding the Site since the early 1940s. Initial construction of industrial facilities occurred under the direction of the United States government during World War II, and subsequent operations have continued through the present. Wastewater effluents from these operations were routed to the Site. Jefferson Canal and Star Lake Canal were excavated in the late 1940s to receive stormwater and industrial wastewater. In approximately February 1983, the Jefferson County Drainage District Number 7 (DD #7) dredged Jefferson Canal by dragline after acquiring an easement on the canal from Texaco Chemical Company (TCC). The DD #7 deposited dredged materials onto the banks of Jefferson Canal in and around an area north of FM Road 366. The deposited dredged material was subsequently determined to be impacted with potentially hazardous constituents. The approximate location of the dredged material is shown on Figure 1-2 of the *Tier 1 RI Report*.

Chevron is currently the parent corporation of Texaco Inc. as a result of a merger in October 2001. Texaco Inc. was the parent corporation of TCC until TCC was sold to

Huntsman in April 1994. TCC was a successor in interest to various entities that operated what are now called the C4 and Oxides and Olefins (O&O) Plants in Port Neches, Texas, and which owned all or part of Star Lake Canal and Jefferson Canal. Huntsman is the current owner of a significant portion of Star Lake Canal and a portion of Jefferson Canal. Huntsman acquired ownership in April 1994 when it purchased TCC. As a result of that acquisition, Huntsman also acquired the C4 and O&O Plants in Port Neches.

The methods and procedures contained in this Draft FS Report describe activities that were conducted during the FS. The remainder of this Draft FS Report is organized into seven sections:

- Section 2.0 includes a timeline of events for the project and a summary of the results of the Tier 1 and Tier 2 RIs. In addition, this section includes a summary of the Alignment Document and the Sensitivity Analysis completed in preparation for the FS scoping.
- Section 3.0 includes identification of the Remedial Action Objectives (RAOs), Applicable or Relevant and Appropriate Requirements (ARARs), constituents of concern (COCs), Preliminary Remediation Goals (PRGs), and general response actions for the FS. This section also includes the screening of potential technology types and process options against effectiveness, implementability, and cost.
- Section 4.0 describes methods and procedures used to assemble the selected general response actions and prepare remedial action alternatives for each Area of Investigation (AOI).
- Section 5.0 describes the process used to further refine the remedial action alternatives and a detailed analysis of the alternatives with respect to the nine evaluation criteria.
- Section 6.0 provides a detailed cost estimate for each of the remedial alternatives within each AOI with a precision of plus 50 percent or minus 30 percent.
- Section 7.0 presents the comparative analysis of the remedial alternatives for each of the seven AOIs of the Site to identify the advantages and disadvantages of each remedial alternative relative to one another within an AOI, and provide key information for use in determination of the selected remedy.

In addition, the Draft FS is supported by figures, tables, and an appendix.

The FS documents alternatives that meet the objective of the RI/FS process and summarizes the advantages, disadvantages, and comparison of all alternatives that were extended through the FS process to include cost estimation.

The RAOs for the Site follow:

Ecological

- Reduce to acceptable levels of toxicity to benthic invertebrates and upper trophic level receptors at the Site from direct contact with COCs in the sediment (A detailed discussion of the COCs is provided in Section 3.1.2 below)
- Reduce to acceptable levels of toxicity to upper trophic level receptors at the Site from direct contact with COCs in the soil of the Jefferson Canal Spoil Pile (A detailed discussion of the COCs is provided in Section 3.1.2 below)

Human Health

- The Human Health Risk Assessment (HHRA) did not identify any potential risk from constituents of potential concern (COPCs) for human receptors that may utilize the Site. Therefore, no RAOs were needed or developed for the protection of human health.

Sediment PRGs were developed for the protection of upper trophic level (UTL) receptors of concern (ROCs) and benthic invertebrates. The ecological PRG, which is protective of both of these receptor groups, is the lowest concentration of the UTL sediment PRG and the benthic invertebrate sediment PRG for each constituent of potential ecological concern (COPEC). According to 30 TAC §350.77, protective concentration levels for ecological receptors are primarily intended to be protective for more mobile or wide-ranging ecological receptors and, where appropriate, benthic invertebrate communities. Therefore, a PRG that protects UTL ROCs and benthic invertebrates in sediment is considered a protective concentration for ecological receptors in sediment and is equal to the ecological sediment PRG.

Soil PRGs were developed for the protection of UTL ROCs. According to 30 TAC §350.77, protective concentration levels for ecological receptors are primarily intended to be protective for more mobile or wide-ranging ecological receptors and, where appropriate, benthic invertebrate communities. Therefore, the UTL soil PRG is considered a protective concentration for ecological receptors and is equal to the ecological soil PRG.

The HHRA did not identify any potential risk from COPCs for human receptors that may utilize the Site. Therefore, no soil or sediment PRGs were needed or developed for the protection of human health.

A list of potentially acceptable technologies and technology process options, corresponding to the identified general response actions, were developed and screened by evaluation of the process options with respect to technical implementability. Each proposed potential technology was further evaluated during the FS for technical implementability, cost, and effectiveness in meeting the RAOs.

The alternative development process focused on the most viable options for remediation of the Site sediment and soil, as appropriate. Alternatives formed for each AOI are as follows:

Jefferson Canal AOI
Alternative 1: No Action
Alternative 2: Containment and 12-inch Removal/Disposal: Pipe Containment
Alternative 3: 12-inch Removal/Disposal and Backfill

Jefferson Canal Spoil Pile AOI
Alternative 1: No Action
Alternative 2a: Containment – without Excavation: Composite Cap
Alternative 2b: Partial Containment – without Excavation: Composite Cap
Alternative 3a: Partial 12-inch Removal/Disposal and Containment: Composite Cap
Alternative 3b: Partial 12-inch Removal/Disposal and Partial Containment: Composite Cap

Former Star Lake AOI
Alternative 1: No Action
Alternative 2: 12-inch Removal/Disposal and Containment: Impermeable Cap
Alternative 3: 12-inch Removal/Disposal and Containment: Soil Cap

Star Lake Canal AOI
Alternative 1: No Action
Alternative 2: 12-inch Removal/Disposal and Containment: Impermeable Cap
Alternative 3: 12-inch Removal/Disposal and Containment: Armored Cap

Gulf States Utility Canal AOI
Alternative 1: No Action
Alternative 2: Containment – without Excavation: Composite Cap
Alternative 3: 12-inch Removal/Disposal and Containment: Armored (protective) Cap
Alternative 4: 12-inch Removal/Disposal

Molasses Bayou AOI – Waterway Polygons
Alternative 1: No Action
Alternative 2: Monitored Natural Recovery
Alternative 3: 12-inch Removal/Disposal and Containment: Armored (protective) Cap

Molasses Bayou AOI – Wetland Polygons
Alternative 1: No Action
Alternative 2: Monitored Natural Recovery
Alternative 3: Containment – without Excavation: Composite Cap
Alternative 4: 12-inch Removal/Disposal and Containment: Armored (protective) Cap
Alternative 5: 12-inch Removal/Disposal

The nine criteria used in the FS process during the evaluation of remedial alternatives provide the framework for conducting a detailed analysis for selection of appropriate remedial actions. These criteria are characterized by the role of the criteria during the remedy selection process. There are threshold, balancing, and modifying criteria to be considered in this evaluation process.

The threshold criteria are:

- Overall protection of human health and the environment
- Compliance with the ARARs

The balancing criteria are:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Short-term effectiveness
- Implementability
- Cost

The modifying criteria are:

- State acceptance
- Community acceptance

The evaluations performed in this FS have identified a number of elements that may require further consideration during the remedial design. Additional sediment and soil data should be obtained in identified locations to more precisely define the horizontal and vertical limits of removal and cap placement to reduce the risk posed by the COCs.

This is crucial at and near pipelines in the vicinity of the Star Lake Canal Superfund Site. At the Jefferson Canal AOI, a hydraulic analysis would be conducted in order to size the pipe to safely convey the design storm event.

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APPENDIX

LIST OF ACRONYMS

AHR	-	Aryl Hydrocarbon Receptor
AOC	-	Administrative Order on Consent
AOI	-	Area of Investigation
ARAR	-	Applicable or Relevant and Appropriate Requirement
ATSDR	-	Agency for Toxic Substances and Disease Registry
AVS	-	Acid-Volatile Sulfide
BERA	-	Baseline Ecological Risk Assessment
CAA	-	Clean Air Act
CCA	-	Copper Chromated Arsenic
CEMC	-	Chevron Environmental Management Company
CERCLA	-	Comprehensive Environmental Response, Compensation, and Liability Act
COC	-	Constituent of Concern
COPCs	-	Constituents of Potential Concern
COPECs	-	Constituents of Potential Ecological Concern
CRA	-	Conestoga-Rovers & Associates
CSM	-	Conceptual Site Model
CT	-	Central Tendency
DDD	-	Dichlorodiphenyldichloroethylene
DDE	-	Dichlorodiphenyldichloroethane
DDT	-	Dichlorodiphenyltrichloroethane
DHHS	-	Department of Health and Human Services
EPA	-	United States Environmental Protection Agency
ERM	-	Effects Range-Median
ERM-Q	-	Effects Range Median Quotient
FS	-	Feasibility Study
GMATC	-	Geometric Mean Acceptable Toxic Concentration
g/mol	-	Grams per mole
H	-	Hazard Ratio
HHRA	-	Human Health Risk Assessment
HI	-	Hazard Index
HQ	-	Hazard Quotient
IARC	-	International Agency for Research on Cancer
K_H	-	Henry's Law constant
K_{OC}	-	Soil organic carbon water partition coefficient
LHHC	-	Limiting Human Health Criteria
LNVA	-	Lower Neches Valley Authority
LOAEL	-	Lowest-Observed Adverse Effects Level

log K_{ow}	-	Octanol/water partition coefficient
mg/day	-	Milligrams per day
mg/kg	-	Milligrams per kilogram
mg/L	-	Milligrams per liter
mg/m^3	-	Milligrams per cubic meter
mmHg	-	Millimeters of mercury
µg/day	-	Micrograms per day
µg/dL	-	Micrograms per deciliter
µg/kg/day	-	Micrograms per kilogram per day
µg/L	-	Micrograms per liter
MNR	-	Monitored Natural Recovery
NAAQS	-	National Ambient Air Quality Standards
NPV	-	Net Present Value
ng/m^3	-	Nanograms per cubic meter
NOAEL	-	No-Observed Adverse Effects Level
NPL	-	National Priorities List
O&M	-	Operation and Maintenance
OMB	-	Office of Management and Budget
OSHA	-	Occupational Safety and Health Administration
PAH	-	Polycyclic Aromatic Hydrocarbon
PCB	-	Polychlorinated Biphenyl
PCDF	-	Polychlorinated Dibenzofurans
PCL	-	Protective Concentration Level
PDS	-	Post Digestion Spike
PEL	-	Probable Effects Level
PEL-Q	-	Probable Effects Level Quotient
Ppm	-	Parts per million
PRG	-	Preliminary Remediation Goal
PRP	-	Potentially Responsible Party
RAGS	-	Risk Assessment Guidance for Superfund
RAO	-	Remedial Action Objective
RBEL	-	Risk Based Exposure Level
RCRA	-	Resource Conservation and Recovery Act
RDA	-	Recommended Dietary Allowance
RI	-	Remedial Investigation
RI/FS	-	Remedial Investigation/Feasibility Study
RME	-	Reasonable Maximum Exposure
ROCs	-	Receptors of Concern

SARA	-	Superfund Amendments and Reauthorization Act
SDWA	-	Safe Drinking Water Act
SEM	-	Simultaneously Extractable Metals
SLERA	-	Screening Level Ecological Risk Assessment
SQL	-	Sample Quantitation Limit
SVOC	-	Semi-Volatile Organic Compound
TCDD	-	2,3,7,8-tetrachloridibenzo[p]dioxin
TCEQ	-	Texas Commission on Environmental Quality
TEF	-	Toxicity Equivalency Factor
TNRCC	-	Texas Natural Resource Conservation Commission
TPWD	-	Texas Parks and Wildlife Department
TRRP	-	Texas Risk Reduction Program
TRV	-	Toxicity Reference Value
TSCA	-	Toxic Substances Control Act
TU	-	Toxic Unit
UCL	-	Upper Confidence Limit
USACE	-	United States Army Corps of Engineers
UTL	-	Upper Trophic Level
VOC	-	Volatile Organic Compound

1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) and Cardno ENTRIX, on behalf of Chevron Environmental Management Company (CEMC) and Huntsman Petrochemical LLC (Huntsman), submit herein to the United States Environmental Protection Agency (EPA) the Draft Feasibility Study (FS) Report for the Star Lake Canal Superfund Site (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Docket No. 06-02-06) located in Jefferson County, Texas (Site). The EPA entered into an Administrative Settlement Agreement and Order on Consent (AOC) for Remedial Investigation/Feasibility Study (RI/FS) with CEMC and Huntsman for the Site on December 22, 2005. The AOC required that a RI/FS be completed for the Site in accordance with relevant EPA Guidance. This submittal is to be used as the basis for the Record of Decision expected subsequently. A vicinity map that shows the location of the Site is included as Figure 1-1.

1.1 OBJECTIVE

The RI/FS process represents the methodology for characterization of the nature and extent of risks posed by potential constituents at a site and for evaluation of potential remedial alternatives for the Site. The objective of the FS is to develop and evaluate a number of alternative methods to achieve the remedial action objectives (RAOs) developed for the Site. The process facilitates proposal of a selected remedy that most appropriately eliminates, reduces, or controls risks to human health and the environment. The FS process includes several steps outlined in EPA guidance including:

- Summary of the results of the RI, the Human Health Risk Assessment (HHRA), the Baseline Ecological Risk Assessment (BERA), and refinement of the conceptual site model (CSM), as necessary
- Establish RAOs and associated preliminary remediation goals
- Identify and screen remedial technology types, general response actions, and specific process options based on Site conditions and constraints
- Assemble the technology types and process options into remedial alternatives and complete screening of remedial alternatives
- Complete a detailed evaluation and comparative analysis of remedial alternatives and recommend a preferred remedy

Preparation and completion of the FS work was consistent with, but not limited to, the following EPA guidance:

- *USEPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, EPA/540/R-05/012, December 2005
- *USEPA Interim Final, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, October 1988
- *USEPA Guidance for Conducting Treatability Studies Under CERCLA,* EPA/540/R-92/071a, October 1992
- *USEPA and USACE A Guide to Developing and Documenting Cost Estimates During the Feasibility Study,* EPA/540/R-00/002, July 2000

1.2 SITE DESCRIPTION

The location of the Site is shown on the vicinity map included as Figure 1-1 and an aerial photograph included as Figure 1-2. The Site includes the two industrial canals (Star Lake Canal and Jefferson Canal) and the adjacent wetlands. Molasses Bayou is located southeast of the Star Lake Canal and intersects the canal at two locations. Gulf States Utility Canal is a canal that was excavated during the placement of a utility line and is located approximately 100 feet northwest of Star Lake Canal. Gulf States Utility Canal extends parallel to Star Lake Canal from northeast of Atlantic Road to the Neches River.

Star Lake Canal and Jefferson Canal are used by nearby industries for permitted discharge of industrial effluents. Historical unpermitted and permitted discharges have resulted in the deposition of potentially hazardous constituents at the Site.

In general, the areas of investigation (AOIs) as discussed in the FS are defined as those areas contiguous to and including potentially impacted media at the Site. During the RI, the Site was divided to include a total of nine AOIs including Star Lake Canal, Former Star Lake, Gulf States Utility Canal, Molasses Bayou Upstream Watercourse, Molasses Bayou Downstream Watercourse, Molasses Bayou Wetland, Jefferson Canal Upstream, Jefferson Canal Downstream, and Jefferson Canal Spoil Piles. The RI sediment, surface water, soil, and biological tissue sample analytical results were used to determine the preliminary nature and extent of the impact at the Site and to delineate AOIs based on areas that require further evaluation. For the FS, the Site is divided into seven AOIs including Jefferson Canal, Jefferson Canal Spoil Pile, Former Star Lake, Star Lake Canal, Gulf States Utility Canal, Molasses Bayou Waterway, and Molasses Bayou Wetland. The Site AOIs are shown on Figure 1-3. A topographic survey map of Jefferson Canal Spoil Pile is included as Figure 1-4.

Figure 1-5 shows several pipelines that run south to north through the Jefferson Canal Spoil Pile. These pipelines were considered during the evaluation of all remedial alternatives for the Jefferson Canal Spoil Pile AOI in this FS submittal.

1.3 SITE HISTORY

Industrial operations have occurred in areas surrounding the Site since the early 1940s. Initial construction of industrial facilities occurred under the direction of the United States government during World War II, and subsequent operations have continued through the present. Wastewater effluents from these operations were routed to the Site. Jefferson Canal and Star Lake Canal were excavated in the late 1940s to receive stormwater and industrial wastewater.

In approximately February 1983, the Jefferson County Drainage District Number 7 (DD #7) dredged Jefferson Canal by dragline after acquiring an easement on the canal from Texaco Chemical Company (TCC). The DD #7 deposited dredged materials onto the banks of Jefferson Canal in and around an area north of FM Road 366. The deposited dredged material was subsequently determined to be impacted with potentially hazardous constituents. The approximate location of the dredged material is shown on Figure 1-2 of the *Tier 1 RI Report*.

Chevron is currently the parent corporation of Texaco Inc. as a result of a merger in October 2001. Texaco Inc. was the parent corporation of TCC until TCC was sold to Huntsman in April 1994. TCC was a successor in interest to various entities that operated what are now called the C4 and Oxides and Olefins (O&O) Plants in Port Neches, Texas, and which owned all or part of Star Lake Canal and Jefferson Canal.

Huntsman is the current owner of a significant portion of Star Lake Canal and a portion of Jefferson Canal. Huntsman acquired ownership in April 1994 when it purchased TCC. As a result of that acquisition, Huntsman also acquired the C4 and O&O Plants in Port Neches. Ameripol Synpol Corporation (Ameripol) is the current owner of a portion of the west-to-east segment of Star Lake Canal.

Property adjacent to and near the Site is owned by various individuals, companies, and agencies. Figure 1-6 shows an outline of the property parcels and lists the property owner, acreage, address, and owner location for each parcel. Over the years, numerous other industrial facilities have conducted operations that have had potential adverse impacts to Star Lake Canal, Jefferson Canal and the Site.

Texas enforcement investigations conducted during the 1970s focused on laboratory detections of pentachlorophenol and toxaphene constituents in Jefferson Canal. Enforcement action in 1983 identified that sediments impacted with toxaphene may have been dredged from the canal and placed on its banks. In 1983, an analytical report from a single sample of disposed dredged material revealed concentrations of toxaphene, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(p)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, fluorene, naphthalene, phenanthrene, pyrene, and biphenyls above the laboratory sample quantitation limits.

On March 21 and March 23, 1983, the Texas Department of Water Resources (TDWR) collected sediment samples from Jefferson Canal, and dredged spoil samples from the banks of Jefferson Canal, and made observations on rainfall and runoff from the dredged materials. Samples were noted to have a strong aromatic odor characteristic of phenolic compounds. The TDWR inspection also revealed rainfall and runoff from dredged materials along the Jefferson Canal bank entering Jefferson Canal. A further review of state records indicated that sampling of dredged materials from Jefferson Canal sediments documented the presence of concentrations of polycyclic aromatic hydrocarbons (PAHs) including naphthalene, acenaphthene, acenaphthylene, fluorene, phenanthrene, anthracene, pyrene, benzo(a)anthracene, benzo-b-fluoranthene, benzo(a)pyrene, benzo-a-fluoranthene, and chrysene at concentrations above the laboratory sample quantitation limits. Soil samples on property adjacent to Jefferson Canal were found to contain toxaphene and possibly pentachlorophenol at concentrations above the laboratory sample quantitation limits.

A Texas Natural Resources Conservation Commission (TNRCC) [presently Texas Commission on Environmental Quality (TCEQ)] Screening Site Inspection (SSI) Report of Star Lake Canal, dated September 1997, indicated that the following constituents were detected in samples collected from Jefferson and Star Lake Canals above the laboratory sample quantitation limit: acenaphthene, acenaphthylene, anthracene, arsenic, barium, benzo(b)fluoranthene, benzo(k)fluoranthene, cyanide, fluoranthene, fluorene, mercury, 2-methylnaphthalene, naphthalene, aroclor-1254 (a polychlorinated biphenyl [PCB]), phenanthrene, pyrene, and thallium. A Table of organic constituents in the samples contained a hand-written entry that indicated that benzo(a)anthracene, chrysene, and benzo(a)pyrene were also detected.

A TNRCC (presently TCEQ) Expanded Site Inspection (ESI) Report for the Star Lake Canal Site, dated January 1999, indicated that samples showed detections of other constituents not listed in the 1997 SSI report, including: acetone, aldrin, benzene, benzo(g,h,i)pyrelene, chromium, copper, 4,4'-DDD, endosulfan I, ethylbenzene, heptachlor epoxide, indeno(1,2,3-cd)pyrelene, selenium, silver, styrene, toluene, and total xylenes. However, arsenic, barium, cyanide, and mercury previously reported in the 1997 SSI report were not reported in the ESI.

On July 22, 1999, the EPA proposed the addition of the Star Lake Canal Site to the National Priority List (NPL). On August 28, 2000, and pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 U.S.C. § 9605) the Site was added to the NPL (40 C.F.R. Part 300, App. B). On December 22, 2005, the AOC was signed by the EPA, CEMC and Huntsman.

1.4 REPORT ORGANIZATION

The methods and procedures contained in this Draft FS Report describe activities that were conducted during the FS. The remainder of this Draft FS Report is organized into seven sections:

- **Section 2.0 – Project Summary -** This section includes a timeline of events for the project and a summary of the results of the Tier 1 and Tier 2 RIs. In addition, this section includes a summary of the Alignment Document and the Sensitivity Analysis completed in preparation for the FS scoping.
- **Section 3.0 – Identification and Screening of Technologies –** This section includes identification of the Remedial Action Objectives (RAOs), Applicable or Relevant and Appropriate Requirements (ARARs), COCs, Preliminary Remediation Goals (PRGs), and general response actions for the FS. This section also includes the screening of potential technology types and process options against effectiveness, implementability, and cost.
- **Section 4.0 –Evaluation of General Response Actions and Development of Remedial Action Alternatives-** This section describes methods and procedures used

to assemble the selected general response actions and prepare remedial action alternatives for each AOI.

- **Section 5.0 – Detailed Analysis of Remedial Action Alternatives -** This section describes the process used to further refine the remedial action alternatives and a detailed analysis of the alternatives with respect to the nine evaluation criteria. .
- **Section 6.0 - Cost -** This section provides a detailed cost estimate for each of the remedial alternatives within each AOI.
- **Section 7.0 – Comparative Analysis of Remedial Alternatives -** This section presents the comparative analysis of the remedial alternatives for each of the seven AOIs of the Site to identify the advantages and disadvantages of each remedial alternative relative to one another within an AOI, and provide key information for use in determination of the selected remedy.
- **Section 8.0 - References -** A list of all references is provided in this section.

In addition, the Draft FS Report is supported by figures, tables, and an appendix.

2.0 PROJECT SUMMARY

The following section provides a timeline of events for the project starting in 2008 and a summary of the results of the Tier 1 and Tier 2 RIs. In addition, this section includes a summary of the Alignment Document and Sensitivity Analysis completed in preparation for the FS scoping.

2.1 TIMELINE OF EVENTS

The Draft Tier 2 RI Work Plan was submitted to the EPA, the TCEQ, and the trustee group on May 16, 2008. CEMC, Huntsman, CRA, and Cardno ENTRIX participated in a meeting with the EPA, the TCEQ, and the trustee group to discuss the Draft Tier 2 RI Work Plan at the TCEQ offices in Austin, Texas on June 5, 2008. The EPA, TCEQ, and the trustee group submitted review comments on the Draft Tier 2 RI Work Plan to CEMC and Huntsman on June 20, 2008. Supplemental information including residential property boundary maps, Federal Emergency Management Agency (FEMA) flood plain maps, and documentation of institutional controls at the Site was submitted to the EPA, TCEQ, and the trustee group on July 11, 2008. Responses to the Draft Tier 2 RI Work Plan comments were submitted to the EPA, TCEQ, and the trustee group on July 31, 2008. A Revised Draft Tier 2 RI Work Plan was submitted to the EPA and the trustees on August 22, 2008. The EPA, TCEQ, and the trustee group submitted review comments on the Revised Draft Tier 2 RI Work Plan on September 23, 2008, September 26, 2008, October 30, 2008, and November 3, 2008. CEMC and Huntsman submitted responses to the review comments on October 15, 2008, and November 18, 2008. A Revised Draft Tier 2 RI Work Plan Addendum, that included additional revisions based on the review comments, was submitted to the EPA, TCEQ, and the trustee group on January 23, 2009. The EPA, TCEQ, and the trustee group submitted review comments on the Revised Draft Tier 2 RI Work Plan Addendum on February 27, 2009. The EPA submitted an approval letter for the Tier 2 RI Work Plan to CEMC on March 9, 2009. On March 13, 2009, CEMC and Huntsman submitted comment responses and the Final Tier 2 RI Work Plan that incorporated all previous revisions was submitted to the EPA, TCEQ, and the trustee group on May 15, 2009.

A Tier 2 RI Work Plan Addendum (Jefferson Canal Spoil Pile Investigation) that outlined the scope of work for the investigation and evaluation of the spoil piles identified on the bank of Jefferson Canal was submitted to the EPA, TCEQ, and the trustee group on October 16, 2009. The EPA, TCEQ, and the trustee group submitted review comments on November 5, 2009, and November 18, 2009. CEMC and Huntsman submitted review comment responses in a correspondence dated December 8, 2009. On February 22, 2010, CEMC and Huntsman requested an extension of the project schedule for completion of the spoil pile investigation prior to submittal of the Draft Tier 2 RI Report. The schedule extension request included a revised submittal date of September 10, 2010. The EPA approved the schedule extension request in an email dated March 1, 2010.

The Tier 2 RI sediment, surface water, soil, and tissue sample collection activities were completed from April 2009 through April 2010. The Draft Tier 2 RI Report was submitted in September 2010. The EPA, TCEQ, and the trustee group submitted review comments on the Draft Tier 2 RI Report in December 2010 and February 2011. On February 15, 2011, a meeting was held between the EPA, CEMC, and Huntsman. The Final Tier 2 RI Report was submitted on April 21, 2011. On June 2, 2011, the EPA issued review comments on the Final Tier 2 RI Report to CEMC and Huntsman and responses to the review comments were submitted by email on June 17, 2011. On July 13, 2011, CEMC and Huntsman submitted a hard copy of the revised pages of the Final Tier 2 RI Report. An electronic copy of the entire Final Tier 2 RI Report with the incorporated revisions was submitted on July 13, 2011. On July 22, 2011, the EPA submitted review comments on the revised pages of the Final Tier 2 RI Report. CEMC and Huntsman submitted responses to the review comments by email on July 29, 2011. The EPA approved the Tier 2 RI Report in a letter dated November 9, 2011.

Concurrent with the Tier 2 Report process, CEMC and Huntsman submitted the Alignment Document on June 17, 2011. During the meeting on February 15, 2011, CEMC agreed to prepare a document that would define those areas within the Site that might contribute the most significant amount of risk to upper trophic level receptors instead of referring to risk across the entire Site. Following submittal of the Alignment Document, a remediation scenario sensitivity analysis was conducted to evaluate the contributions of the various soil and sediment sample areas to overall Site risk.

Representatives of EPA, TCEQ, CEMC, Huntsman, CRA, Cardno ENTRIX, and the trustee group participated in FS scoping meetings/conference calls on June 28, 2011, August 31, 2011, September 14, 2011, October 13, 2011, and November 9, 2011 at the EPA offices in Dallas, Texas and by telephone. The meetings/conference calls included discussion of the Final Tier 2 RI Report, the Alignment Document, the remediation scenario sensitivity analysis, the project schedule, and the FS Work Plan.

In a letter dated December 5, 2011, the EPA requested that preliminary remedial alternatives be developed to address Scenarios 10b and 11b developed during the sensitivity analysis. The EPA also requested a project schedule to include completion of the Draft FS by March 31, 2012. On December 29, 2011, CEMC and Huntsman submitted a preliminary evaluation of remedial alternatives to the EPA. The correspondence included a summary of the proposed scope of work and schedule for completion of the FS. On December 29, 2011, CEMC and Huntsman submitted a preliminary evaluation of remedial alternatives to the EPA. This evaluation included a summary of the proposed scope of work and schedule for completion of the FS.

On January 27, 2012, CRA on behalf of CEMC and Huntsman submitted the Draft FS Work Plan to the EPA, in accordance with the proposed project schedule dated December 29, 2011. On February 3, 2012, a letter received from the EPA requested a meeting with representatives of CEMC and Huntsman at the Region 6 office in Dallas to discuss the proposed alternatives and required submittal of the Draft FS by April 16, 2012. A letter dated February 24, 2012 was received from the EPA for clarification on dates for completion of the Draft FS and the March 1, 2012 submittal of remedial alternatives that will be evaluated in the Final FS. On March 1, 2012, Chevron and Huntsman submitted the Preliminary Evaluation of Remedial Alternatives and a schedule for the FS to the EPA. These documents were submitted in response to the EPA letters dated February 3 and February 24, 2012. On March 9, 2012, CRA and Cardno ENTRIX on behalf of Chevron and Huntsman submitted Draft PRGs to the EPA for review. Representatives of EPA, TCEQ, CEMC, Huntsman, CRA, Cardno ENTRIX, and the trustee group participated in an FS meeting/conference all on March 19, 2012, at the EPA offices in Dallas, Texas, to discuss the March 1, 2012, and March 9, 2012, submittals.

2.2 REMEDIAL INVESTIGATION SUMMARY

The following sections provide a summary of results for the Tier 1 and Tier 2 RIs, presents an ecological CSM and a human health CSM for the Site, and summarizes the findings of the HHRA and the BERA.

2.2.1 TIER 1 RI SAMPLE COLLECTION SUMMARY

The Tier 1 RI sediment and surface water sample locations are shown on Figure 2-1.

Surface Water

A total of 31 surface water samples were collected from the Site at 31 sample locations, 8 samples from Star Lake Canal, 7 samples from Jefferson Canal, 3 samples from Gulf States Utility Canal, and 13 samples from Molasses Bayou.

Sediment

A total of 104 sediment samples were collected from the Site at 54 locations, 27 samples from 9 locations in Star Lake Canal, 21 samples from 7 locations in Jefferson Canal, 9 samples from 3 locations in Gulf States Utility Canal, and 47 samples from 35 locations in Molasses Bayou.

Surface sediment samples represent the top six inches of sediment and were collected in areas that may have accumulated re-suspended sediment and/or erosion materials and represent a less dynamic erosion/sedimentation system. Mid and refusal depth sediment samples represent the middle and bottom six inches of sediment, respectively. Mid-depth and refusal depth sediment samples were obtained where significant inflows and a more dynamic erosion/sedimentation system have the potential to bring in large volumes of water possibly laden with erosional material and where historical surface sediment sample collection revealed detectable concentrations of constituents. Surface, mid-depth, and refusal depth sediment samples were collected from all locations in Star Lake Canal, Jefferson Canal, and Gulf States Utility Canal. Surface sediment samples were collected from 35 locations throughout Molasses Bayou. Mid-depth and refusal depth sediment samples were collected from six locations, MB-1, MB-18, MB-21, MB-24, MB-27, and MB-28 in Molasses Bayou.

Soil

A total of four soil samples were collected from the Site at four locations along the western bank of Jefferson Canal. The soil samples were collected along the western bank of Jefferson Canal between the Lower Neches Valley Authority (LNVA) Canal and the Star Lake Canal in the area where dredged material spoil piles had been identified in the previous investigations. Tier 1 RI soil sample locations are shown on Figure 2-3.

2.2.2 TIER 2 RI SAMPLE COLLECTION SUMMARY

This section provides a detailed summary of the samples collected during the Tier 2 RI. The Tier 2 RI sediment and surface water sample locations are shown on Figure 2-2.

Surface Water

A total of 34 surface water samples were collected from the Site at 34 sample locations during the Tier 2 RI, 2 samples from Star Lake Canal, 7 samples from Gulf States Utility Canal, 7 samples from Molasses Bayou Upstream, 5 samples from Molasses Bayou Downstream, 7 samples from Jefferson Canal Upstream, and 6 samples from Jefferson Canal Downstream AOIs.

Surface water samples were collected at two locations, SLC-10 and SLC-11, in Star Lake Canal, on April 8, 2009, and April 14, 2009, respectively. Surface water samples were collected from seven locations, GSUC-4 through GSUC-10, in Gulf States Utility Canal on April 14 and 15, 2009, respectively. Surface water samples were collected from seven locations, MB-49, MB-52, MB-53, MB-54, MB-57, MB-60, and MB-61, in the Molasses Bayou Upstream Watercourse AOI on April 8, 2009, and April 15, 2009. Surface water samples were collected from five locations, MB-36 and MB-43 through MB-46, in the Molasses Bayou Downstream Watercourse AOI on April 15 and 16, 2009. Surface water samples were collected from four locations, JC-18 through JC-21, in Jefferson Canal Upstream AOI on April 16 and 17, 2009. In addition, surface water samples were collected from three locations, JC-22 through JC-24, in the stormwater conveyance within the Huntsman PNPP facility on April 16, 2009. Surface water samples were collected from six locations, JC-12 through JC-17, in Jefferson Canal Downstream AOI on April 16, 2009.

Sediment

A total of 154 sediment samples were collected from the Site at 64 locations during the Tier 2 RI, 6 samples from 2 locations in Star Lake Canal, 30 samples from 10 locations in Former Star Lake, 29 samples from 9 locations in Gulf States Utility Canal, 23 samples from 8 locations in Molasses Bayou Upstream Watercourse, 15 samples from 7 locations in Molasses Bayou Downstream Watercourse, 14 samples from 14 locations in Molasses Bayou Wetland, 23 samples from 8 locations in Jefferson Canal Upstream, and 30 samples from 10 locations in Jefferson Canal Downstream AOIs.

Surface (0- to 6-inch) sediment samples represent the top six inches of sediment and were collected in areas that may have accumulated re-suspended sediment and/or erosion materials and represent a less dynamic erosion/sedimentation system. The 6- to 12-inch and 12- to 18-inch sediment samples represent the middle and bottom six inches of sediment, respectively. The 6- to 12-inch and 12- to 18-inch sediment samples were obtained where significant inflows and a more dynamic erosion/sedimentation system have the potential to bring in large volumes of water possibly laden with erosional material and where historical surface sediment sample collection revealed detectable concentrations of constituents. In addition, 12- to 18-inch and 18- to 24-inch sediment samples were collected to provide vertical delineation of impacted sediment at several locations across the Site.

The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from Star Lake Canal in 2 locations, SLC-10 and SLC-11, on April 8 and 14, 2009. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from Former Star Lake in 10 locations, SL-1 through SL-10, on April 7 and 8, 2009. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from 7 locations, GSUC-4 through GSUC-10, and 12- to 18-inch and 18- to 24-inch sediment samples were collected from GSUC-2R and GSUC-3R in Gulf States Utility Canal on April 6, 2009. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from seven sample locations, MB-49, MB-52, MB-53, MB-54, MB-57, MB-60, and MB-61, and 12- to 18-inch and 18- to 24-inch sediment samples were collected from one location, MB-18R, in Molasses Bayou on April 6 and 7, 2009. Three 0- to 6-inch sediment samples were collected from three sample locations, MB-39, MB-42, and MB-46, and the 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from four sample locations, MB-36, and MB-43 through MB-45, in Molasses Bayou on April 7 and 8, 2009. Fourteen 0- to 6-inch sediment samples were collected from 14 sample locations, MB-37, MB-38, MB-40, MB-41, MB-47, MB-48, MB-50, MB-51, MB-55, MB-56, MB-58, MB-59, MB-62, and MB-63 in the Molasses Bayou Wetland AOI on April 7, 2009. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from four locations, JC-18 through JC-21, and 12- to 18-inch and 18- to 24-inch sediment samples were collected from one location, JC-5R, in Jefferson Canal on April 14 through April 16, 2009. In addition, 9 sediment samples (3 samples from 3 locations) were collected from the stormwater conveyance within the Huntsman PNPP facility. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from three locations, JC-22 through JC-24, in the most upstream portion of Jefferson Canal, in the stormwater conveyance within the Huntsman PNPP facility, on April 16, 2009. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from four locations, JC-1 through JC-4, in Jefferson Canal on October 18 and 19, 2006. The 0- to 6-inch, 6- to 12-inch, and 12- to 18-inch sediment samples were collected from six locations, JC-12 through JC-17, in Jefferson Canal on April 9, 2009.

Soil

A total of 104 samples were collected from 25 soil borings installed in and around the spoil pile material in the Jefferson Canal Spoil Pile AOI on April 21 through 27, 2010. A total of eight borings, JCSP-1 through JCSP-8, were installed in the identified spoil material to a depth of approximately 60 inches (five feet) below the typical ground surface. Samples were collected from each of the spoil material borings from a location within the spoil material, at depth intervals of 0 to 6 inches, 6 to 12 inches, 12 to 24 inches, and at the total depth of the boring (54 to 60 inches) bgs. A total of 17 soil borings (JCSP-9 through JCSP-25) were installed in areas around the perimeter of the identified spoil material to a depth of approximately 60 inches (5 feet) bgs for delineation of the horizontal extent of potential soil impact from the spoil material. Samples were collected from each of the perimeter borings at depth intervals of 0 to 6 inches, 6 to 12 inches, 12 to 24 inches, and 54 to 60 inches bgs.

Additional sample intervals were collected at four soil boring locations based on material characteristics and stratigraphy. Borings JCSP-3, JCSP-12, JCSP-21, and JCSP-24 were advanced to depths of 20, 15, 20, and 25 feet, respectively, based on visual observations at the time of sample collection. In addition, one geotechnical soil boring (GT-2 [0 to 5 feet]) was installed at a location in the spoil material and one geotechnical soil boring (GT-1 [0 to 5 feet]) was installed in an area around the perimeter of the identified spoil material to identify material characteristics. Tier 2 RI soil sample locations are shown on Figure 2-3.

Tissue

The biological tissue investigation included collection of 40 tissue samples for use in the HHRA and 70 tissue samples for use in the BERA. Tissue samples were collected under the Texas Parks and Wildlife Department (TPWD) Scientific Research Permit Number SPR-0808-313. The Tier 2 RI biological tissue sampling included collection of 110 fish tissue composite samples from locations across the Site that were accessible by human or watercraft and that represented reasonable habitats for the target species. The biological tissue sample collection activities were completed from April through October 2009.

Fish tissue samples collected for use in the HHRA were collected from the open-channel, fishable portions of Star Lake Canal and Molasses Bayou. Tissue samples collected for use in the BERA were from areas throughout the Site that represented likely habitats for the Receptors of Concerns (ROCs) and their prey.

Approximately half of the pelagic fish tissue samples (PELFISH-01 through PELFISH-05) consisted of spotted gar (*Lepisosteus oculatus)* and were collected from Star Lake Canal just downstream of the dam. The remaining portion of the pelagic fish tissue samples (PELFISH-11 through PELFISH-13, PELFISH-15, and PELFISH-17) consisted of black drum (*Pogonias cromis*), red drum (*Sciaenops ocellatus*), and spotted sea trout (C*ynoscion* *nebulosus*) and were collected from the most downstream portion of Star Lake Canal at its confluence with the Neches River. Bottom feeding fish samples were collected primarily from Star Lake Canal and portions of Molasses Bayou at its confluence with Star Lake Canal. The bottom feeding fish samples (BOTFISH-1, BOTFISH-02, BOTFISH-04, and BOTFISH-06 through BOTFISH-10) consisted of hardhead catfish (*Arius felis)*. In addition, bottom feeding fish samples (BOTFISH-03 and BOTFISH-05) consisted of southern flounder (*Paralichthys lethostigma)*. Shellfish samples were collected primarily from Star Lake Canal and portions of Molasses Bayou. Shellfish samples (CRAB-01 TISSUE through CRAB-10 TISSUE) consisted entirely of blue crab (*Callinectes sapidus*). Additional shellfish samples (CRAB-01 HEP through CRAB-10 HEP) collected for analysis of the hepatopancreas tissue were also collected primarily from Star Lake Canal and portions of Molasses Bayou and consisted entirely of blue crab.

Ecological fish tissue samples were collected primarily from Star Lake Canal, Gulf States Utility Canal and Molasses Bayou. Ecological fish were collected in two size ranges (1 to 6 inches) and (6 to 12 inches) to assess potential risk various feeding guilds. Ecological fish tissue samples (ECO-FISH(1-6)-01 through ECO-FISH(1-6)-10) consisted of composites of croaker (*Micropogonias undulatus*), and other species including fathead minnow (*Pimephales promelas)* and gulf menhaden (*Brevoortia patronus*) Ecological fish tissue samples (ECO-FISH[6-12]-01 through ECO-FISH[6-12]-10) consisted primarily of striped mullet *(Mugil cephalus*). Ecological shellfish samples were collected primarily from Star Lake Canal and portions of Molasses Bayou at its confluence with Star Lake Canal. Shellfish samples (ECO-CRAB-01 through ECO-CRAB-10) consisted entirely of whole body blue crab (*Callinectes sapidus*). Blue crab for the ecological evaluation were not subject to the 5 inch width regulation and were collected in the same manner as the HHRA crab tissue samples.

Terrestrial and aquatic emergent insect samples (ECO-INSECT-01 through ECO-INSECT-10) were collected from both upland and wetland areas throughout the Site. The majority of insect samples were collected on the upland areas in and around Star Lake Canal, Molasses Bayou, and downstream Jefferson Canal. Insect samples were collected using light traps. Vegetation samples (ECO-VEG-01 through ECO-VEG-10) included alligator weed (*Alternanthera philoxeroides*) were collected throughout the Site in wetland and fringe areas. Terrestrial invertebrates (ECO-WORM-01 through ECO-WORM-04 and ECO-WORM-06 through ECO-WORM-11) samples were collected primarily from the spoil pile area near the downstream portion of Jefferson Canal. The terrestrial invertebrate samples consisted entirely of earthworms (*Lumbricus terrestris)*. The ecological amphibian samples (ECO-FROG-01 through ECO-FROG-10) consisted entirely of frogs, with the majority being bullfrogs (*Rana catesbiena*), that were collected primarily from the downstream portion of Jefferson Canal and portions of Molasses Bayou.

Mussels and other mollusks were not available at the Site for sample collection. Several attempts were made to collect these species in their suitable habitats, but no tissue samples were able to be collected.

2.2.3 CONCEPTUAL SITE MODEL

This section identifies and discusses the constituent fate and transport mechanisms at the Site and the various potential human and ecological exposure pathways to the constituents. A CSM of constituent fate and transport to ecological receptors is presented on Figure 2-4. A CSM of constituent fate and transport to human receptors is presented on Figure 2-5. As shown on the figures, historical discharges from surrounding industry are the primary source of potential impact at the Site. Constituents were discharged to surface water and sediments in both Jefferson Canal and Star Lake Canal and subsequently to other areas and environmental media within the Site by various transport mechanisms including sediment re-suspension, surface water transport, dredging sediment, and erosion of sediment spoil piles.

The different exposure pathways for general groups of potential receptors chosen for this RI are shown on Figure 2-4 and Figure 2-5. Potential ecological receptors include shorebirds, waterfowl, songbirds, mammals, reptiles and amphibians, fish, and terrestrial and aquatic invertebrates. Potential human receptors that may use portions of the Site include recreational users, industrial workers, fishermen/shell fishers, and trespassers.

All the AOIs at the Site are accessible via navigable waterways, with the exception of the upstream portion of Jefferson Canal. Therefore, a recreational user was considered as a potential human receptor in the Star Lake Canal, Former Star Lake, Gulf States Utility Canal, Molasses Bayou Upstream, Downstream, and Wetland, and Jefferson Canal Downstream AOIs. A trespasser was considered as a potential human receptor in the Jefferson Canal Upstream AOI. The Site is not considered public property available for access by the general public; however, because it is potentially accessible for use by the public, a recreational use exposure scenario was considered the most appropriate.

Industrial worker populations that utilize the Site could not be identified. Huntsman personnel confirmed that they do not use the portions of Jefferson Canal Downstream, Star Lake Canal, Former Star Lake, and Gulf States Utility Canal AOI on the Huntsman property. Without an identified industrial worker population, an exposure frequency for an industrial worker in these AOIs could not be estimated and human health risk estimates could not be calculated. An industrial worker exposure scenario was considered for the Jefferson Canal Upstream AOI to account for the portion of the AOI in the stormwater conveyance in the Huntsman PNPP facility. An industrial worker exposure scenario was also considered for the Jefferson Canal Spoil Pile AOI to account for any pipeline or water control maintenance activities that may take place in that area. A recreational user was considered as a conservative potential receptor substitute for any potential industrial workers in the Star Lake Canal, Former Star Lake, Gulf States Utility Canal, Molasses Bayou Upstream, Downstream, and Wetland, and Jefferson Canal Downstream AOIs.

2.2.3.1 BANK SOIL

Bank (upland) soil is restricted to areas where dredged material from Jefferson Canal was deposited and remains.

Ecological exposure pathways include potential uptake by terrestrial plants and insect dietary items and incidental ingestion by some of the receptors of concern (ROCs) including song birds and mammals.

Jefferson Canal Spoil Pile AOI

Impacted sediment was dredged from Jefferson Canal and the spoils were placed in an upland area (bank soil) bordering the western portion of the canal. Erosion of these upland dredged soils is considered a secondary source of potential surface water and canal sediment impact. The lowest of the TCEQ Texas Risk Reduction Program (TRRP) Tier 1 Commercial/Industrial Soil Protective Concentration Levels (PCLs) for a 30 acre source area were used to evaluate surface soil in the Tier 1 and 2 RI. The Tier 1 Commercial/Industrial Soil PCLs include ingestion, dermal contact, inhalation of volatiles and particulates, ingestion of above-ground and below-ground vegetables ($^{Tot}Soil_{Comb}$), and inhalation of volatile emissions from constituents of concern (COCs) in subsurface soil ($^{Air}Soil_{Inh\text{-}V}$). The PCLs for soil-to-groundwater leaching to class 1 and 2 groundwater ($^{GW}Soil_{Ing}$), soil-to-groundwater leaching for volatilization ($^{Air}GW\text{-}Soil_{Inh\text{-}V}$) were not evaluated during the screening of the soil data. The Huntsman PNPP facility plans to prohibit the use of groundwater on their property. Huntsman will impose a deed restriction on their property that restricts groundwater use for any purpose. The Huntsman property boundary is shown on Figure 7-3 of the *Tier 2 RI Report*. Subsurface soil data was collected only during the Tier 2 RI. Human exposure pathways for bank soil include potential incidental ingestion, dermal contact, and inhalation by industrial workers at the Site.

2.2.3.2 AIR

Evaporation of volatile constituents and particulates from bank soil is considered a potential route of exposure in the CSM. The potential inhalation of bank soil volatile emissions by recreational users, industrial workers, and trespassers is discussed above. Based on the Tier 1 and 2 RI surface water sample data, the evaporation of volatile constituents from surface water exposure pathway is considered incomplete in the CSM for all AOIs.

The pathway is considered potentially complete, but not evaluated for ecological receptors as inhalation of such constituents by burrowing mammals is not expected to be an ecologically significant exposure pathway. Potential inhalation of dust particles by wildlife has been estimated to contribute less than 0.1% of total risk compared to risk from oral exposures (USEPA 2005).

2.2.3.3 GROUNDWATER

Huntsman is currently conducting a groundwater corrective action monitoring program at the PNPP facility. The objective of the groundwater corrective action monitoring program is to document the existing groundwater plume geometry and monitor the effectiveness and progress of naturally occurring biodegradation processes that are attenuating and degrading the COCs in the groundwater within the two uppermost water-bearing zones beneath the facility.

As part of the Tier 1 and Tier 2 RI, the potential communication between groundwater beneath the Huntsman facility and the surface water in the upstream portions of Star Lake Canal and Jefferson Canal was evaluated to determine if the existing groundwater plume beneath the Huntsman facility represents a continuing source of impairment to sediment and surface water in Star Lake Canal and Jefferson Canal. (Section 10.0 of the Tier 2 RI Report).

Groundwater to sediment and surface water exposure pathways are potentially complete as the groundwater impact related to the Huntsman facility is adjacent the Star Lake Canal Superfund Site; however, the related risk assessment of the groundwater exposure pathways (inhalation, ingestion, and dermal contact) is currently being evaluated under TCEQ's Corrective Action Program as part of the Huntsman Site-Wide Groundwater investigation. In addition, the potential groundwater to surface water interaction identified in both Star Lake Canal and Jefferson Canal in the RI has not resulted in identification of constituents in surface water or sediment that pose unacceptable human health or ecological risk. Details regarding the investigation and risk assessment conducted as part of the Huntsman Site-Wide Groundwater Corrective Action Monitoring Program are detailed in Section 10.3 of the *Tier 2 RI Report* and an evaluation of the groundwater, surface water, and sediment constituents is presented in Section 10.4 of the *Tier 2 RI Report*.

2.2.3.4 CANAL SEDIMENT

The historical discharge from surrounding industry was the primary source of impact to the canal sediment in both Star Lake Canal and Jefferson Canal. Sediment is defined in the CSM as a substrate that is partially or permanently inundated with water, including canal and wetland sediment. Canal sediment is considered to be permanently inundated with water as in Star Lake Canal, Jefferson Canal, and Gulf States Utility Canal watercourses.

Potential exposure pathways for ecological receptors include uptake by aquatic invertebrate and fish dietary items and direct ingestion.

Star Lake Canal

EPA Region 4 Risk Assessment Guidance for Superfund (RAGS) Human Health Risk Assessment Bulletin states that "in most cases it is unnecessary to evaluate human exposures to sediments covered by surface water" (*USEPA. 2000. Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment Bulletins. EPA Region 4, originally published November 1995, Website version last updated May 2000*). Canal sediment in the Star Lake Canal watercourse is considered to be covered by surface water at all times, therefore ingestion and dermal contact exposure pathways to all human receptors in this AOI is considered incomplete. However, the Tier 1 and 2 RI sediment data was compared to the TCEQ TRRP sediment Protective Concentration Levels (PCLs) (protective of dermal contact and ingestion by a recreational user) during the human health screening evaluation, as a conservative measure to identify potential constituents that may require further investigation. The Star Lake Canal Tier 1 and Tier 2 RI sediment data were compared to the sediment PCLs protective of dermal contact and ingestion during the human health screening evaluation, but the pathway will be considered incomplete as identified on the CSM in the risk calculations for the HHRA. Ingestion by fish/shellfish consumption for a fisher/shellfisher in Star Lake Canal is considered complete.

Gulf States Utility Canal

Dermal contact exposure to canal sediments by recreational users, industrial workers, and fishermen in Gulf States Utility Canal is considered complete. Incidental ingestion of canal sediment by recreational users and industrial workers is also considered complete in the Gulf States Utility Canal AOI. The sediment exposure pathway was evaluated for dermal contact and ingestion using the Tier 1 Sediment PCLs. The sediment exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Gulf States Utility Canal AOI is considered complete and was evaluated based on tissue sample results.

Molasses Bayou Upstream and Downstream Watercourse AOIs

Dermal contact exposure to canal sediments by recreational users, industrial workers, and fishermen in Molasses Bayou AOIs is considered complete. Incidental ingestion of canal sediment by recreational users and industrial workers is also considered complete in the Molasses Bayou AOIs. The sediment exposure pathway was evaluated for dermal contact and ingestion using the Tier 1 Sediment PCLs. The sediment exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in Molasses Bayou AOIs is considered complete and was evaluated based on tissue sample results.

Jefferson Canal Upstream

Dermal contact and incidental ingestion exposure to canal sediments by industrial workers and trespassers in the Jefferson Canal Upstream AOI is considered complete. Exposure to the recreational user and fisherman/shell fisher receptors was considered incomplete due to the presence of fencing as administrative controls to prevent access by those receptors. The sediment exposure pathway was evaluated for dermal contact and ingestion using the Tier 1 Sediment PCLs. The sediment exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for trespassers in the Jefferson Canal Upstream AOI is considered incomplete as there is not a measurable quantity of fish in this portion of the canal available for catching. In addition, the upstream portion of Jefferson Canal is not hydraulically connected to the downstream portion and fish cannot swim from the downstream to the upstream portion.

Jefferson Canal Downstream

Dermal contact exposure to canal sediments by recreational users and fishermen in Jefferson Canal Downstream is considered complete. Incidental ingestion of canal sediment by recreational users is also considered complete in the Jefferson Canal Downstream AOI. The sediment exposure pathway was evaluated for dermal contact and ingestion using the Tier 1 Sediment PCLs. The sediment exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Jefferson Canal Downstream AOI is considered complete and was evaluated based on tissue sample results.

2.2.3.5 WETLAND SEDIMENT

Re-suspension of canal sediment into surface water and deposition of the sediments in the surrounding wetland (non-watercourse) areas of the Site was the primary route of impact to the wetland sediment. Sediment is defined in the CSM as a substrate that is partially or permanently inundated with water, including canal and wetland sediment. Wetland sediment is considered to be partially inundated with water as in the Molasses Bayou Wetland and Former Star Lake AOIs.

Potential exposure pathways to wetland sediment for human receptors include dermal contact, ingestion of sediment, and indirect exposure via ingestion of fish/shellfish. Direct contact pathways, i.e., ingestion of sediment and dermal contact with sediment for intermittent waterbodies are evaluated for the sediment not continuously covered by water.

Potential exposure pathways for ecological receptors include uptake by wetland plant and invertebrate dietary items and indirect ingestion.

Former Star Lake

Dermal contact and incidental exposure to wetland sediment by recreational users and fishermen in Former Star Lake is considered complete. Incidental ingestion of wetland sediment by recreational users is also considered complete in the Former Star Lake AOI. The sediment exposure pathway was evaluated for dermal contact and ingestion using the Tier 1 Sediment PCLs. The sediment exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Former Star Lake AOI is considered complete and was evaluated based on tissue sample results.

Molasses Bayou Wetland

Dermal contact exposure to wetland sediment by recreational users and fishermen in Molasses Bayou Wetland is considered complete. Incidental ingestion of wetland sediment by recreational users is also considered complete in the Molasses Bayou Wetland AOI. The sediment exposure pathway was evaluated for dermal contact and ingestion using the Tier 1 Sediment PCLs. The sediment exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Molasses Bayou Wetland AOI is considered complete and was evaluated based on tissue sample results.

2.2.3.6 SURFACE WATER

The primary source of impact to the surface water at the Site is from historical discharge from surrounding industry. Re-suspension of canal sediment and erosion of the upland bank soil, and the potential communication with the existing groundwater plume at the Huntsman facility are secondary sources of impact.

Potential exposure pathways for ecological receptors include uptake by aquatic invertebrates and indirect ingestion.

Star Lake Canal

Dermal contact exposure to surface water by recreational users and fishermen in the Star Lake Canal AOI is considered complete. Incidental ingestion of surface water by recreational users is also considered complete in the Star Lake Canal AOI. The surface water exposure pathway was evaluated for dermal contact using the approved Contact Recreation Water PCLs. The surface water exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Star Lake Canal AOI is considered complete and was evaluated based on tissue sample results.

Gulf States Utility Canal

Dermal contact exposure to surface water by recreational users and fishermen in Gulf States Utility Canal is considered complete. Incidental ingestion of surface water by recreational users is also considered complete in the Gulf States Utility Canal AOI. The surface water exposure pathway was evaluated for dermal contact using the approved Contact Recreation Water PCLs. The surface water exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Gulf States Utility Canal AOI is considered complete and was evaluated based on tissue sample results.

Molasses Bayou Upstream and Downstream Watercourse AOIs

Dermal contact exposure to surface water by recreational users and fishermen in Molasses Bayou AOIs is considered complete. Incidental ingestion of surface water by recreational users is also considered complete in the Molasses Bayou AOIs. The surface water exposure pathway was evaluated for dermal contact using the approved Contact Recreation Water PCLs. The surface water exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in Molasses Bayou AOIs is considered complete and was evaluated based on tissue sample results.

Jefferson Canal Upstream

Dermal contact and incidental ingestion exposure to surface water by industrial workers and trespassers in the Jefferson Canal Upstream AOI is considered complete. Exposure to the recreational user and fisherman/shell fisher receptors was considered incomplete due to the presence of fencing as administrative controls to prevent access by those receptors. The surface water exposure pathway was evaluated for dermal contact using the approved Contact Recreation Water PCLs. The surface water exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for trespassers in the Jefferson Canal Upstream AOI is considered incomplete and was not evaluated further. A representative of the US Fish and Wildlife Service conducted a Site visit during the Tier 2 RI tissue sample collection activities and confirmed that there were no fish available for collection in Jefferson Canal.

Jefferson Canal Downstream

Dermal contact exposure to surface water by recreational users and fishermen in Jefferson Canal Downstream is considered complete. Incidental ingestion of surface water by recreational users is also considered complete in the Jefferson Canal Downstream AOI. The surface water exposure pathway will be evaluated for dermal contact using the approved Contact Recreation Water PCLs. The surface water exposure pathway for protection of ingestion of freshwater and saltwater fish/shellfish for Site fishermen in the Jefferson Canal Downstream AOI is considered complete and was evaluated based on tissue sample results.

2.2.3.7 FISH/SHELLFISH

The potential source of impact to the fish/shellfish tissue at the Site is from the ingestion of potentially impacted surface water and canal/wetland sediment by fish and shellfish. The exposure pathway to human receptors is through human consumption (direct ingestion) of the fish and shellfish tissue.

The Tier 2 RI fish/shellfish tissue samples were obtained primarily from Star Lake Canal and portions of Molasses Bayou. The Tier 2 RI fish tissue sample results were used to evaluate potential human health exposure to recreational fishermen in the Star Lake Canal, Former Star Lake, Gulf States Utility Canal, and Jefferson Canal Downstream AOIs. The Jefferson Canal Downstream, Gulf States Utility Canal, Former Star Lake, and portions of Molasses Bayou Wetland AOIs are not expected to yield fish/shellfish of legal size for human consumption.

Star Lake Canal

Ingestion of fish/shellfish tissue by a recreational fisher/shellfisher in Star Lake Canal is considered complete. The fish consumption exposure pathway was evaluated using the TCEQ TRRP risk based exposure levels (RBELs) for ingestion of saltwater fish/shellfish tissue.

Gulf States Utility Canal

Ingestion of fish/shellfish tissue by a recreational fisher/shellfisher in the Gulf States Utility Canal AOI is considered complete. No human health fish/shellfish tissue samples were collected from this AOI. The fish consumption exposure pathway was evaluated using the TCEQ TRRP RBELs for ingestion of freshwater and/or saltwater fish/shellfish tissue.

Molasses Bayou Upstream and Downstream Watercourse
Ingestion of fish/shellfish tissue by a recreational fisher/shellfisher in the Molasses Bayou Upstream and Downstream Watercourse AOIs is considered complete. The fish consumption exposure pathway was evaluated using the TCEQ TRRP RBELs for ingestion of freshwater and/or saltwater fish/shellfish tissue.

Jefferson Canal Downstream
Ingestion of fish/shellfish tissue by a recreational fisher/shellfisher in the Jefferson Canal Downstream AOI is considered complete. No human health fish/shellfish tissue samples were collected from this AOI. The fish consumption exposure pathway was evaluated using the TCEQ TRRP RBELs for ingestion of freshwater fish/shellfish tissue.

2.2.3.8 ECOLOGICAL TISSUE

This section provides a summary of the Tier 1 and Tier 2 HHRA results and conclusions.

The potential source of impact to the ecological upper trophic receptors at the Site is from the ingestion of potentially impacted surface water and canal/wetland sediment, soil, and dietary items. The exposure pathway to ecological upper trophic level receptors is through consumption (direct ingestion) of the dietary items at the Site (i.e., insects, vegetation, amphibians, fish, shellfish and invertebrates) and incidental ingestion of constituents through sediments, soil, and surface water.

The Tier 2 RI ecological tissue samples include insects, earthworms, amphibians, fish, shellfish, and vegetation and were obtained from locations throughout the Site. The Tier 2 RI tissue sample results were used to evaluate potential upper trophic level receptor exposure to constituents in Star Lake Canal, Former Star Lake, Gulf States Utility Canal, Molasses Bayou Upstream and Downstream Watercourse, Molasses Bayou Wetland, Jefferson Canal Upstream, Jefferson Canal Downstream, and Jefferson Canal Spoil Pile AOIs.

2.2.4 HUMAN HEALTH RISK ASSESSMENT

The Tier 1 RI screening criteria were selected from available sources developed by USEPA and TCEQ using standard default exposure scenarios that may not be applicable to the Site. For example, contact recreation risk based exposure levels (RBELs) for surface water are based on recreational swimming. For many of the AOIs, wading was the appropriate potential recreational activity because of the shallow surface water depth in the AOI. In these cases, the Tier 1 RI screening criteria were overly conservative resulting in detection limits that exceeded the associated RBELs for certain constituents. If Site-specific RBELs were used during the Tier 1 RI screening process, there would have been few constituents with detection limits that exceeded RBELs.

These surface water and sediment RBELs for protection of fish consumption were obsolete in the Tier 2 RI because fish tissue samples were collected and analyzed in the Tier 2 RI and these tissue analyses were used to develop health based risk estimates for fish consumption. The use of surface water and sediment RBELs derived for the protection of fish consumption increased the number of constituents with detection limits higher than RBELs.

For constituents with all non-detects in a particular medium, it is unclear whether these constituents (a) are not present at the Site, (b) are present, but at concentrations below the associated limiting human health criteria (LHHC), or (c) are present at concentrations above the associated LHHC, but below the standard quantitation limits (SQLs). USEPA (1989b) indicates that constituents should generally be eliminated from the risk assessment if they are not detected in any sample of a particular medium unless there is evidence they are present. This provision affects the majority of the constituents with detection limits that exceed RBELs, i.e., all analyses were non-detect in a particular medium. The constituents listed in the following sections were not eliminated from evaluation based on percentage frequency of detection. The available analytical data were reviewed and evaluated to determine whether the constituents were likely to be present in a specific medium given (a) results in other AOIs, and (b) results in other media. If the constituents were not detected in other AOIs or in any other medium, then the non-detected constituent was not considered to be an AOI-specific or Site-specific COPC.

Surface Water

Tier 1 RI surface water screening criteria were based on the lower of RBELs for fish ingestion or for recreational swimming. Toxaphene and PCB-1260 were not detected in any sample from any of the AOIs. In addition, PCB-1254, PCB 126, and dibenz(a,h)anthracene were not detected in nearly all AOIs. Therefore, consistent with USEPA (1989b), these constituents are unlikely to be Site-specific surface water COPCs. As such, no further evaluation of these constituents in surface water was warranted.

Detection limits for five constituents analyzed in surface water from the Molasses Bayou Downstream Watercourse AOI exceeded screening criteria. These constituents included PCB-1248, bis(2-ethylhexyl)phthalate, hexachlorobenzene, N-nitrosodi-n-propylamine, and pentachlorophenol. The detection limits for only one sample result for each of these constituents exceeded the screening criteria. For the remaining six samples, all detection limits were below screening criteria. As such, none of these constituents are regarded as Site-specific surface water COPCs, and therefore, no further evaluation of these constituents in the Molasses Bayou Downstream Watercourse AOI surface water was warranted.

With respect to PCB-1248 in the Molasses Bayou Downstream Watercourse AOI, the same result is noted, i.e., only one detection limit that exceeded the screening criteria. Detection limits for the remaining 12 samples were all below the screening level. As such, PCB-1248 is not regarded as a Site-specific surface water COPC in the Molasses Bayou Downstream Watercourse AOI, and therefore, no further evaluation of PCB-1248 in the Molasses Bayou Downstream Watercourse AOI surface water was warranted.

The detection limits for arsenic in the Molasses Bayou Wetland AOI surface water exceeded the screening criteria. However, the Tier 1 RI screening criteria for arsenic was based on protection of fish ingestion by humans. Arsenic was included in the analytical test program for fish tissue and therefore, the Tier 1 RI screening criteria is not applicable for identifying constituents for inclusion in quantitative risk estimates with respect to fish ingestion. All detection limits for arsenic in the Molasses Bayou Wetland AOI were below the recreational swimming RBEL. As such, no further evaluation of arsenic in the Molasses Bayou Wetland AOI surface water was warranted.

Sediment

As noted above for surface water, Tier 1 sediment criteria were based on the lower of RBELs for fish ingestion or for recreational swimming. For certain AOIs (Star Lake Canal), contact with sediments was considered an incomplete exposure pathway because of surface water depth.

The Tier 1 screening criterion for PCB 126 was based on protection of fish ingestion by humans. PCB 126 was included in the analytical test program for fish tissue and therefore, the Tier 1 RI screening criterion is not applicable for identifying constituents for inclusion in quantitative risk estimates with respect to fish ingestion. All detection limits for PCB-126 in these AOIs were below the recreational swimming RBEL. As such, no further evaluation of non-detected PCB 126 was warranted.

For dieldrin in the Former Star Lake AOI sediment samples, only one detection limit exceeded associated screening criteria in surface sediment (0-6 inches). Detection limits in the remaining nine samples were all below screening criteria. As such, dieldrin is not regarded as a Site-specific sediment COPC in the Former Star Lake AOI, and therefore, no further evaluation of this constituent in the Former Star Lake AOI sediment was warranted.

One detection limit each for PCB-1016, to PCB-1221, and PCB-1232 exceeded associated screening criteria in surface sediment (0-6 inches) samples from the Jefferson Canal Upstream AOI. Detection limits in the remaining nine samples were all below screening criteria. As such, these constituents are not regarded as Site-specific sediment COPCs in the Jefferson Canal Upstream AOI, and therefore, no further evaluation of these constituents in the Jefferson Canal Upstream AOI sediment was warranted.

Soil

No constituents in soil samples collected from the Jefferson Canal Spoil Pile AOI had detection limits that were higher than the screening criteria.

Tissue

There were 7 non-detected constituents in fish tissue samples that had detection limits that were higher than screening criteria. These constituents included 4 semi-volatile organic compounds (SVOCs), 2 PAHs, and 1 pesticide. Because detection limits in more than one composite tissue sample exceeded the fish ingestion RBEL, concentrations of these seven constituents in surface water, sediment, and ecological tissue samples were evaluated. If the constituent was not detected in any of these samples, no further evaluation was completed. If these constituents were detected in any sample, further evaluation with respect to (a) detection limits and RBELs and (b) estimated potential risks assuming concentrations of ½ the detection limit was completed.

Table 8-25 of the *Tier 2 RI Report* shows that neither 3,3'-dichlorobenzidine or bis(2-chloroethyl)ether was detected in surface water, sediment, or ecological tissue samples (3,3'-dichlorobenzidine was not analyzed in ecological tissue samples). As such, these constituents are not regarded as Site-specific COPCs in fish tissue. For hexachlorobenzene, pentachlorophenol, and toxaphene, 100% or nearly 100% of detection limits were below RBELs for freshwater and all ½ detection limit values were below RBELs for tidal saltwater. As such, these constituents are regarded as unlikely to pose an unacceptable risk to human health, even if present. Finally, carcinogen risk estimates for benzo(a)pyrene and dibenz(a,h)anthracene using the maximum ½ detection limit value ranged from 1.46E-05 for tidal freshwater to 3.21E-05 for tidal saltwater sources. These risk estimates are well below the target level of 1.00E-04 and therefore no further evaluation was warranted.

Based on the information presented in the HHRA, the following conclusions were made:

i) The HHRA evaluated potential human health impacts associated with exposure to COPCs identified in surface water, sediment, soil, and biological tissue collected at the Site.

ii) The potential exposure scenarios evaluated at the Site considering the current and potential future use of the Site included: recreational fishing, recreational swimming/wading, trespass wading, industrial (maintenance) worker, and industrial (outdoor) worker.

iii) The calculated central tendency (CT) and reasonable maximum exposure (RME) carcinogen risks and non-carcinogen hazard indexes (HIs) for all exposure scenarios for all receptors were below the target levels specified in USEPA (1991) and TCEQ (2008) of 1.00 x 10^{-4} for cancer risk and 1.0 to 10 for hazard index. All RME estimates for all scenarios, with the exception of recreational wading in Molasses Bayou Downstream, fall within the $1x10^{-4}$ to $1x10^{-6}$ cancer risk range (Tables 8-14, 8-16, 8-18, 8-19, 8-20, and 8-21 of the *Tier 2 RI Report*). In addition, several of the CT estimates fall within the $1x10^{-4}$ to $1x10^{-6}$ cancer risk range (Tables 8-15, 8-17, 8-19, and 8-20 of the *Tier 2 RI Report*).

2.2.5 BASELINE ECOLOGICAL RISK ASSESSMENT

This section provides a summary of the BERA results and conclusions completed during the Tier 2 RI.

In the BERA, declines in health and viability of avian, reptilian, terrestrial mammal, fish, and terrestrial, aquatic and benthic invertebrate receptor populations were identified as the assessment endpoints. These assessment endpoints were evaluated with information obtained from measurement endpoints to determine if reduced survival, impaired reproduction, or growth inhibition in local ROC populations was likely a result of exposure to COPECs at the Site. For this phase of the assessment, multiple lines of evidence were evaluated for selected receptors to reduce some of the uncertainties associated with making decisions based on a single line of evidence. Table 9-25 of the *Tier 2 RI Report* details each line of evidence used for sediment samples at the Site and the risk management decision concerning risk to benthic receptors. Table 9-26 of the *Tier 2 RI Report* shows the risk level for each COPEC-upper level trophic receptor pair.

The specific measurement endpoints used in this BERA include data quantifying the occurrence and magnitude of concentrations of COPECs in surface sediments (including wetland sediments), soils, surface water, and selected biological tissues within the study area. These data permit the evaluation of ecological risks to ecological receptors exposed to COPECs in abiotic media and via the food chain. More realistic exposures of upper trophic level ROCs to COPECs were assessed by using measured tissue concentrations in dietary prey items (e.g., blue crab, forage fish) in the exposure models.

Potential risks from COPECs were evaluated for terrestrial, aquatic and benthic invertebrates through Hazard Ratio (H)-values for both terrestrial and aquatic invertebrates, and through Effects Range-Median (ERM)-Quotient (Q)/ Probable Effects Level (PEL)-Q, H values, Toxic Units (TUs), and Simultaneously Extractable Metals (SEM)/Acid-Volatile Sulfide (AVS) ratios for benthic invertebrates.

2.2.5.1 BENTHIC INVERTEBRATES

A total of 19 freshwater sediment and 94 estuarine or saltwater sediment samples were collected during the RI. The following analyses/comparisons were made as part of the evaluation of multiple lines of evidence:

- Utilization of Sediment Quality Guidelines (ERM and PEL)
- Comparisons of concentrations to State and Federal Benchmarks (H values)
- Determination of the SEM/AVS ratio
- Calculation of Toxic Units (PAHs and five non-ionic organics)

Lines of Evidence Analysis

A preferential line of evidence analysis was used to form a decision regarding whether the sediment sample would be addressed in the FS or the sediment sample required no further action. This method for decision making was as follows: a sediment sample will be addressed in the FS if the sample has high or medium-high ERM-Q/PEL-Q priority status or if the sample has medium-low ERM-Q/PEL-Q priority status with an additional Line of Evidence exceedance (Midpoint H > 1, TU >1, SEM/AVS >1); a sediment sample will require no further action if the sample has medium-low ERM-Q/PEL-Q priority status with no additional line of evidence exceedance or if the sample has low ERM-Q/PEL-Q priority status. The results for each line of evidence at each sediment sample location and the resulting risk management decision based on the preferential line of evidence analysis are provided in Table 9-25 of the Tier 2 RI Report.

Freshwater Sediment

The results of the preferential lines of evidence assessment indicated that all samples in Jefferson Canal and one sample in Star Lake Canal (SLC-8) will need to be addressed in the FS for potential remedial action. The samples in the highest PEL-Q risk category were found to have risk mostly driven by pesticides (4'4-DDE and dieldrin), PCBs, and PAHs. While these COPECs analyzed with the PEL-Q method did not have detected concentrations high enough to meet the criteria for a high or med-high priority status in the remaining Jefferson Canal samples, several other COPECs did exceed midpoint benchmarks. The COPECs that were elevated beyond midpoint benchmark levels in the samples with med-low PEL-Q risk priority status included several metals (iron, manganese, silver) and pesticides (aldrin, lindane, heptachlor epoxide, and toxaphene). Based on PELs, total PAH benchmarks, and TUs, PAHs appear to be posing risk at only those samples that are in the high PEL-Q risk priority category (JC-2, JC-7, JC-13, JC-18, and JC-19).

Saltwater Sediment

The results of the preferential lines of evidence assessment indicated that the majority of the Molasses Bayou Downstream Watercourse AOI samples, with the exception of MB-34, MB-44, and MB-42, do not pose unacceptable risk and therefore, do not require further action. Conversely, a large percentage of the Molasses Bayou Upstream Watercourse AOI sediment samples will be addressed in the FS due to potential risk to benthic receptors. Based on the preferential lines of evidence analysis, the COPECs that appear to be driving this potential risk in the Molasses Bayou upstream watercourse are 4'4-DDT, lead, mercury, Dieldrin, PAHs, and gamma-BHC. Of the 94 saltwater sediment sample locations within the Site, only six sample locations, all within Molasses Bayou (MB-10, MB-14, MB-21, MB-24, MB-56 and MB-63), had concentrations that exceeded the second effects level benchmark for total PAHs, representing concentrations that will cause adverse effects to benthic invertebrates. Of those six locations, two of them (MB-10 and MB-21) had TU values that also exceeded 1.0, denoting risk posed to benthic invertebrates due to the additive narcotic toxicity of PAHs and non-ionic organics. Gulf States Utility Canal, Former Star Lake, and Star Lake Canal did not have risk confined to certain geographical areas of each respective AOI; the sediment samples that will be addressed in the FS were found in variable locations within these AOIs.

2.2.5.2 TERRESTRIAL INVERTEBRATES

Within soil, each constituent at each sample location was compared to the ecological benchmark where benchmarks were available. Results indicate that within the Jefferson Canal Spoil Pile AREA, each of the 30 sampling locations had exceedances of ecological benchmarks for at least one of the following: dieldrin, barium, chromium (total), cobalt, lead, manganese, mercury, selenium, silver, vanadium, and zinc. Total chromium, vanadium, and dieldrin were found to have the highest hazard ratios when comparing benchmarks to Site Reasonable Maximum Exposures (RMEs) and sample means. Since all benchmarks found in TCEQ (2006) for soil exposure to terrestrial invertebrates are first effects levels, these very conservative benchmarks were used for comparison to soil sample concentrations at the Site. It is likely that risk to terrestrial invertebrates is overestimated due to these conservative benchmarks; nevertheless, all samples will be addressed in the FS to further evaluate this potential risk.

2.2.5.3 AQUATIC INVERTEBRATES AND FISH

Comparison to Aqueous Benchmarks

When comparing reasonable maximum exposure concentrations in freshwaters with appropriate ecological benchmarks, data indicated that aquatic invertebrates and fish would be exposed to concentrations that could pose risk and therefore, will be addressed in the FS. Data indicate that some metals, pesticides, PCBs and volatiles exceeded their applicable benchmark. It is important to note that for many of the COPECs with H>1, the constituents were not detected at or above the sample quantitation limit (SQL). Non-detected constituents with H>1 include some metals, Aroclors, volatile organic compounds (VOCs) and pesticides. Twelve of the 100 COPECs with applicable ecological benchmarks had detected concentrations that resulted in H>1. Detected constituents collected in 2006 with H>1 include aluminum (total), copper (dissolved), iron (total), magnesium (total), manganese (total), vanadium (total), dieldrin, endosulfan II and pentachlorophenol. Detected constituents collected in 2009 with H>1 include aluminum (total), calcium, iron (total), magnesium (total), manganese (total), endosulfan I, heptachlor epoxide and pentachlorophenol.

When comparing reasonable maximum exposure concentrations in saltwater with appropriate ecological benchmarks, data indicated that aquatic invertebrates and fish would be exposed to concentrations that might indicate some risk. Data indicate that some metals, pesticides and volatiles exceeded their applicable benchmark. Risk is likely overestimated for many of the COPECs with H>1, as most of those constituents were not detected at or above the sample quantitation limit. Non-detected constituents with H>1 include several pesticides and VOCs.

Sediment to Fish Pathway

A comparison of concentrations of COPECs in tissues to literature-derived tissue residue data was made in an attempt to further determine if effects on fish would be expected at the Site. In general, there were few exceedances of COPECs above literature-derived tissue residue values. The constituents that were found at levels determined to be a potential risk to fish include: aluminum, barium, iron, copper, lead, manganese, chromium, zinc, endosulfan II and total PAHs. Although data indicate that some metals, endosulfan II and total PAHs might exceed concentrations where effects could be expected, most fish are very transient and it is likely that exposure to metals does not come solely from the Site.

2.2.5.4 UPPER TROPHIC LEVEL RECEPTORS

Risk to UTL ROCs from exposure to each COPEC was assessed in the Tier 2 RI Report through exposure modeling using Site-specific dietary and media COPEC concentrations. Exposure factors, such as body weight, food ingestion rate, soil/sediment ingestion rate, water ingestion rate, dietary items, and home range, were used in estimating the dose of each constituent to which the ROC is exposed. Estimates of total daily dose were calculated for each ROC-COPEC pair and divided by an effects concentration to equal the Hazard Quotient (HQ). The HQs were determined for each COPEC-receptor pair using the Site-wide RME concentrations in sediment, soil, surface water, and dietary items. An HQ≤1.0 indicated that risk is acceptable (EPA 1998). Alternatively, an HQ>1.0 indicated an unacceptable risk and resulted in the decision to address the sample in the FS. The calculated HQs for each COPEC-receptor pair are provided in Table 9-23 of the Tier 2 RI Report.

Risk was further defined as low (or acceptable) if the $HQ_{[NOAEL]}$, $HQ_{(GMATC)}$, or $HQ_{(LOAEL)}$ values are less than one. Risk was considered to be indeterminate if the $HQ_{[NOAEL]}$ >1 while the $HQ_{(GMATC)}$ and $HQ_{(LOAEL)}$ <1. Risk was considered probable if the $HQ_{(GMATC)}$ >1 and the $HQ_{(LOAEL)}$ <1. Risk was considered high if the $HQ_{(LOAEL)}$ >1 or if a threatened and endangered species has a $HQ_{(NOAEL)}$, $HQ_{(GMATC)}$, or $HQ_{(LOAEL)}$ >1. The COPEC exposures that are addressed in the FS are those that resulted in an indeterminate, probable, or high risk. Identification of these COPECs that are causing potential risk to the ROCs allows for identification of specific geographic areas in the Site that have COPEC concentrations at or above levels that result in an Hazard Quotient (HQ)>1. Additionally, any COPEC-ROC pair showing risk due to ingestion of mollusks or mammals could potentially be an overly conservative risk estimate. These prey items were not collected at the Site, so mollusk and mammal concentrations used in the exposure models were based on sediment and soil concentrations and a literature-derived BAF. An evaluation of these conservative risk estimates was recommended for the FS.

Two VOCs, ethylbenzene and carbon disulfide, indicated indeterminate and probable risk to the spotted sandpiper and the marsh wren, respectively. Exposure levels in the remaining thirteen receptor models had acceptable risk for VOCs. Exposure models indicate high exposure risks from hexachlorobenzene to the bullfrog, painted turtle, mallard, marsh wren, spotted sandpiper, raccoon and the short-tailed shrew. Pentachlorophenol had indeterminate exposure risks to the spotted sandpiper and high exposure risks to the painted turtle, raccoon, and short-tailed shrew. Benzaldehyde showed indeterminate exposure risk in the belted kingfisher model. PCBs evaluated as PCB congeners ($\sum TEQ_{PCB}$) had indeterminate exposure risk to the short-tailed shrew and the raccoon. Total PAHs were determined to be a high risk to the short-tailed shrew and an indeterminate risk to the raccoon and muskrat. Endosulfan II and endrin pose probable risk to the raccoon and indeterminate risk to the American robin, respectively. Risks to all upper trophic level receptors with the exception of the brown pelican, green heron, and reddish egret, indicated general risk from exposure to metals Site-wide. The results of the exposure model assessment indicated that no COPEC exposure posed unacceptable risk to the state endangered brown pelican, state threatened reddish egret, and green heron. The state threatened wood stork, white-faced ibis, and alligator snapping turtle (painted turtle as surrogate) were found to be at potential risk from exposure to several COPECs.

The dietary item (daily dose) that contributed the majority of risk for ROC-COPEC pairs with HQ > 1 was identified to determine if risk was being driven by a particular environmental medium (i.e. soil, sediment, surface water) or by a combination of lower trophic dietary items and ingestion of COPECs directly from the environment. Each ROC-COPEC pair with a HQ > 1 is discussed in the *Tier 2 RI Report* . Table 9-27 of the

Tier 2 RI Report provides a summary of the dietary or environmental media that is driving risk.

2.2.6 REMEDIAL INVESTIGATION CONCLUSIONS

The Tier 1 RI Report objectives were met with the presentation of the results of the Tier 1 RI including the determination of the preliminary nature and extent of impact at the Site and the identification of potential ecological and human health risk. The Tier 1 HHRA screening process and the Screening Level Ecological Risk Assessment (SLERA) indicated that COPCs and COPECs are present at the Site at concentrations that may pose human health or ecological risk. The Tier 1 RI sample locations are shown on Figure 2-1.

The Site characterization and sampling plan was based on a source and pathway approach to data collection. The source of the impact was defined as the historical discharge of upstream industries. Constituents were discharged into the surface water bodies of Jefferson Canal and Star Lake Canal. Subsequently the constituents were transported to other areas of the Site and other environmental media within the Site via mechanisms including deposition, sediment re-suspension, surface water transport, dredging, and erosion. Therefore, Tier 1 and 2 RI sample locations were placed at locations along, and adjacent to, the potential transport pathways. Constituents were detected in sample media including soil, surface water, and sediment at various locations throughout the transport pathways. Sufficient data was collected in order to adequately identify the horizontal and vertical extent of COPCs and COPECs in sediment, soil, and surface water at the Site.

To assess the potential for risk to human receptors from exposure to these constituents by way of the various media, a human health risk assessment (HHRA) was completed. The HHRA established screening level human health criteria for constituents based on existing guidance documents and identified environmental media in certain areas of the Site in which specific constituent concentrations exceeded the screening level human health criteria for different exposure pathways. The HHRA included an exposure assessment, toxicity assessment, and risk characterization, using conservative assumptions, with the COPCs identified in the screening level HHRA. Calculated risk estimates for all receptors evaluated were either below or within the acceptable cancer risk range of $1x10^{-6}$ to $1x10^{-4}$ and below the noncancer hazard index of 1.0 defined by USEPA for Superfund sites. The acceptable cancer risk range established in CERCLA states that the upper end of the risk range usually applies to residential areas and sensitive populations, and the lower end of the risk range typically applies to commercial/industrial uses. Groundwater was not addressed in this HHRA and is being evaluated under the TCEQ Corrective Action Program; this is discussed briefly in Section 2.2.3.3 and in detail in Section 10.0 of the Tier 2 RI Report.

To assess the potential for risk to ecological receptors from exposure to constituents at the Site, a BERA was completed. In the BERA, declines in health and viability of avian, reptilian, terrestrial mammal, fish, and terrestrial, aquatic and benthic invertebrate receptor populations were identified as the assessment endpoints. These assessment endpoints were evaluated with information obtained from measurement endpoints to determine if reduced survival, impaired reproduction, or growth inhibition in local ROC populations was likely a result of exposure to COPECs. For this phase of the assessment, multiple lines of evidence were evaluated for selected receptors to reduce the uncertainties associated with making decisions based on a single line of evidence.

The specific measurement endpoints used in the BERA include data quantifying the occurrence and magnitude of concentrations of COPECs in surface sediment (including wetland sediment), soil, surface water, and selected biological tissue within the study area. The results of these data were evaluated to estimate ecological risks to ecological receptors exposed to COPECs in abiotic media and via the food chain. Exposures of upper trophic level ROCs to COPECs were assessed using measured tissue concentrations in dietary prey items (e.g., blue crab, forage fish) in the exposure models. Potential risks from COPECs were evaluated for terrestrial, aquatic, and benthic invertebrates with H ratios for both terrestrial and aquatic invertebrates, and with H ratios, ERM-Q/PEL-Q, and TUs for benthic invertebrates. The BERA determined that potential widespread ecological risk exists for benthic invertebrates, terrestrial invertebrates, aquatic invertebrates, fish, and some upper trophic level ROCs due to exposure to certain constituents at the Site.

Based on the various lines of evidence evaluated at the Site, the results indicate that concentrations of metals in sediment, surface water, soil, and tissue samples and concentrations of several pesticides in sediment, surface water, and fish tissue samples appear to influence the majority of risk potential to the ROCs at the Site. While there are multiple soil and sediment sample locations that have constituent concentrations that were addressed in the FS, in general, there is a subset of locations in either freshwater or saltwater areas that appear to be influencing much of the risk estimated to upper trophic level receptors. These locations, which will be further evaluated in the FS for their risk contribution, generally consist of soil sample locations in the Jefferson Canal spoil pile area and sediment sample locations in the Jefferson Canal area, the Former Star Lake area, and locations typically confined to the Molasses Bayou upstream watercourse. Evaluations on COPEC exposure levels in three state-threatened upper trophic level receptors, the white-faced ibis, wood stork, and alligator snapping turtle (painted turtle used as surrogate) resulted in some risk potential from several metals and SVOCs. The information contained in this BERA is intended to support decisions regarding the evaluation of potential future remedial actions within the Site.

2.3 ALIGNMENT DOCUMENT

CEMC and Huntsman submitted the Alignment Document on June 17, 2011. The purpose of the Alignment Document was to provide a bridge between the Tier 2 RI and the FS for the Site. In the Tier 2 RI and the BERA, risks to benthic invertebrates were quantified on a sample location basis while risks to UTL ROCs were determined on a Site-wide basis. The Alignment Document helped to define those areas of the Site that might contribute the most significant amount of risk to UTL ROCs instead of referring to risk across the Site.

DEVELOPMENT OF THIESSEN POLYGONS

The Site was delineated into decision units surrounding each sediment and soil sample location using a Thiessen polygon approach (See Figures 1 and 2 of the *Alignment Document*). Thiessen polygons are used to mathematically define individual areas around each of a set of points. The boundaries of each of these polygons define areas that are statistically closest to each point relative to all other points. So, if a particular point is found to contribute significantly to risk, then the boundary represented by the polygon surrounding that point would be considered to contribute significantly to that risk.

BENTHIC INVERTEBRATE RISK APPLIED TO THIESSEN POLYGONS

Four lines of evidence were used in the BERA to evaluate risk to benthic and epibenthic organisms: Hs, ERM-Qs/PEL-Qs, SEM/AVS, and TUs. A preferential line of evidence analysis was used to form a decision regarding whether the sediment sample location would be addressed in the FS or the sediment sample location required no further action. Results of the preferential lines of evidence analysis were applied to the Thiessen polygons in Figure 3 of the *Alignment Document*.

UPPER TROPHIC LEVEL RISK APPLIED TO THIESSEN POLYGONS

To define those areas that might be considered drivers of upper trophic level risk, sediment and soil protective concentration levels (PCLs) were calculated for the ROCs that were determined to have unacceptable risk from a particular COPEC. Unacceptable risk was defined by an indeterminate, probable, or high risk (i.e. an $HQ_{[NOAEL]}$ >1, $HQ_{(GMATC)}$, or $HQ_{(LOAEL)}$ <1 in the *Tier 2 RI Report*.

PCLs were determined using the dose equation method (see Equations 1 and 2 of the *Alignment Document*) outlined in the Texas Natural Resource Conservation Commission (TNRCC) Guidance for Conducting Risk Assessments at Remediation Sites in Texas (2001). The ecological PCL is the concentration of a COPEC within an exposure medium which is protective of the more wide-ranging receptors that may frequent the Site and utilize the less mobile receptors as a food source (TNRRC 2001). In the dose equation method, a single media-specific PCL is calculated while COPEC concentrations in other media are held constant. As such, the sediment PCL was calculated as the COPEC concentration in sediment that would result in a HQ = 1 while soil and water COPEC concentrations are held at constant concentrations. Conversely, the soil PCL was calculated as the COPEC concentration in soil that results in a HQ = 1 while sediment and water COPEC concentrations are held at constant concentrations. Soil PCLs were only calculated for those receptors with greater than 1% of soil in their diet (raccoon, short-tailed shrew, and American robin) and a HQ>1.

A large percentage of the total daily dose for most receptors was due to ingestion of dietary items. Because the constituent concentrations in dietary items were dynamically linked to sediment or soil concentrations, the revised dose equations utilized Site-specific bioaccumulation factors (BAFs) to model tissue concentrations given a decrease in soil and sediment constituent concentration. The BAF value is calculated as the ratio of the concentration of a constituent in an organism's tissue to the concentration in an environmental medium to which the organism is exposed (see Equation 3 in the *Alignment Document*). The Site-specific BAF was calculated for each receptor and then used in place of the RME concentrations of the dietary items that were used in the Tier 2 RI exposure models.

For those COPECs with a GMATC HQ>1 or a NOAEL HQ>1 for T&E species, the sediment and soil PCLs for each ROC were compared to the COPEC concentrations in each polygon. Figures 4 through 20 in the *Alignment Document* show the number of ROCs (out of the 15 total ROCs at the Site) with PCL exceedances at each sediment polygon. Figures 21 through 27 in the *Alignment Document* show the number of ROCs (out of the 15 total ROCs at the Site) with PCL exceedances at each soil polygons. PCL exceedances were used to identify the hot spot locations that are driving risk to upper trophic level ROCs.

While performing the PCL analysis, it was determined that there were overly conservative measures used in the hexachlorobenzene risk calculation. Re-evaluation of the hexachlorobenzene risk levels determined that a number of the hexachlorobenzene PCLs did not need to be calculated due to an overly conservative mollusk BAF. This nonempirically-derived BAF was replaced with a field-measured mollusk BAF resulting in acceptable risk levels for the short-tailed shrew, raccoon, mallard, bullfrog, and painted turtle. Therefore, calculations of hexachlorobenzene PCLs were not necessary for those ROCs.

CONCLUSIONS

By applying the Thiessen polygons to the Site and showing the areas that are contributing to upper trophic level risk, remedial alternatives can be evaluated or interpreted on a sediment or soil sample area basis instead of a Site-wide basis. Upper trophic level PCL values and PCL exceedance values at each polygon location were presented in the *Alignment Document* and were further used during the *Sensitivity Analysis* to determine the areas that contributed a majority of the risk to UTL ROCs and to establish PRGs. In addition, showing the benthic risk decisions as Thiessen polygons allows the remedial alternatives to be evaluated or interpreted for benthic invertebrates on an area basis instead of a point to point basis.

2.4 SENSITIVITY ANALYSIS

The Sensitivity Analysis was completed to assess the reduction in Site-wide risk to UTL ROCs that would occur given a variety of remediation scenarios in sediment and soil. These remediation scenarios evaluated PRGs in sediment and soil, as well as the sediment and soil locations that need to be addressed in the FS.

2.4.1 EVALUATION OF UPPER TROPHIC LEVEL RISK

Risk to UTL ROCs from exposure to each COPEC was assessed in the *Tier 2 RI Report* through exposure modeling using Site-specific dietary and media COPEC concentrations. The HQ characterized UTL risk in which HQs ≤ 1 indicated no risk for adverse ecological effects and HQs > 1 indicated some potential for adverse effects. Each ROC-COPEC pair determined to have an HQ > 1 was retained for further evaluation in the Sensitivity Analysis (Table 2-1).

2.4.2 DEVELOPMENT OF REMEDIATION SCENARIOS

In the Alignment Document, PCLs for UTL receptors were developed and compared to Site concentrations in sediment and soil (see Section 2.3). The ROCs with PCL exceedances within each polygon was evaluated and presented in the Alignment Document. While this evaluation did present the frequency of PCL exceedances it did not address the magnitude of the exceedance. The magnitude of a PCL exceedance can help identify the hot spot areas that will be most successful in reducing risk to UTL ROCs given a remediation of that area. Sediment and soil sample locations with UTL PCL exceedances were assessed for their individual contributions to overall Site-risk by comparing the magnitudes of all PCL exceedances among samples, which aided in a determination of UTL risk hot spots. These hot spot locations were identified by first dividing the COPEC concentration at a sample location by the UTL PCL of the corresponding COPEC, as follows:

$$PCL\ Exceedance\ Ratio_{sed} = \frac{C_{sed}}{PCL_{sed}}$$

or

$$PCL\ Exceedance\ Ratio_{soil} = \frac{C_{soil}}{PCL_{soil}}$$

Where:

PCL Exceedance Ratio $_{sed}$ = PCL Exceedance for a UTL ROC-COPEC pair at a sediment sample location (unitless)

PCL Exceedance Ratio $_{soil}$ = PCL Exceedance for a UTL ROC-COPEC pair at a soil sample location (unitless)

C_{sed} = COPEC concentration at the corresponding sediment sample location (mg/kg dry weight)

C_{soil} = COPEC concentration at the corresponding soil sample location (mg/kg dry weight)

PCL_{sed} = PCL in sediment for a UTL ROC-COPEC pair (mg/kg dry weight)

PCL_{soil} = PCL in soil for a UTL ROC-COPEC pair (mg/kg dry weight)

The PCL exceedance ratios were then summed for all of the COPECs at each sample location, as follows:

$$\textit{Total PCL Exceedance Ratio}_{sediment} = \sum \textit{PCL Exceedance Ratio}_{sediment}$$

or

$$\textit{Total PCL Exceedance Ratio}_{soil} = \sum \textit{PCL Exceedance Ratio}_{soil}$$

Where:

PCL Exceedance Ratio $_{sediment}$ = PCL Exceedance for a UTL ROC-COPEC pair at a sediment sample location (unitless)

PCL Exceedance Ratio $_{soil}$ = PCL Exceedance for a UTL ROC-COPEC pair at a soil sample location (unitless)

Total PCL Exceedance Ratio $_{sediment}$ = Sum of all PCL Exceedance Ratios in sediment for all UTL ROC-COPEC pairs at the corresponding sample location (unitless)

Total PCL Exceedance Ratio $_{soil}$ = Sum of all PCL Exceedance Ratios in soil for all UTL ROC-COPEC pairs at the corresponding sample location (unitless)

The sample locations that are significantly contributing to the Site-wide risk to UTL ROCs are those sample locations with the highest Total PCL Exceedance Ratios. Sediment and soil sample locations were grouped according to their total ratio number and then illustrated on Thiessen polygon maps (Figures 2-6 and 2-7). The Total PCL Exceedance Ratios were used during the Sensitivity Analysis to evaluate the areas that contributed a majority of the risk to UTL receptors and to evaluate various PRGs for their potential to reduce risk to UTL ROCs to an acceptable level (HQ ≤ 1).

The EPA also requested for an evaluation of scenarios that remediate areas showing risk to benthic invertebrates. Benthic invertebrate risk was assessed with several lines of evidence in the Tier 2 RI. The ERM-Q and PEL-Q was the primary line of evidence to confer risk to benthic invertebrates because this method evaluates notable metals, PAHs, PCBs, and pesticides using 2nd effects level benchmarks to assess the toxicological significance of the mixture. Using this line of evidence as the risk management strategy, several remediation scenarios were developed that evaluated remediation of any sediment sample with an ERM-Q and PEL-Q Priority Categories Score of three or four, corresponding to medium-high and high risk categories, respectively (Scenarios 10 and 11).

Description of the remediation scenarios that were evaluated in the Sensitivity Analysis are provided in Table 2-2.

2.4.3 REFINEMENT OF COPEC LIST FOR SENSITIVITY ANALYSIS

For all remediation scenarios, HQs were calculated for each effects level (NOAEL, GMATC, and LOAEL). To further refine the risk characterization and COPEC list for which PRGs should be established in the FS, the EPA recommended that acceptable risk to UTL receptors could be defined as any COPEC in which the $HQ_{[NOAEL]} < 1$ for T&E receptors and the $HQ_{[GMATC]} < 1$ for all other non-T&E receptors. Based on this approach, benzaldehyde, hexachlorobenzene, nitrobenzene, PCB congeners, endrin, and zinc were not carried forward into the FS. These COPECs were determined to result in acceptable UTL risk levels at the Site under the current Site conditions. See Table 2-3 for a list of the COPECs retained and the COPECs not carried forward into the FS.

2.4.4 THIESSEN POLYGONS

Thiessen polygons were developed in the *Alignment Document* using sediment and soil sample locations to establish areas to be used as decision units in the FS. During the Sensitivity Analysis phase of the FS, the EPA recommended a revision to the polygon boundaries based on geographical features and recommended using the AOI boundaries from the RI investigation as boundaries for the revised Thiessen polygons. The reason for this request was to reduce the number of habitat types included in each polygon, thereby reducing the types of remedial actions to be considered within each polygon.

The Thiessen polygons are illustrated in Figure 2-8 and were reviewed by the EPA and trustees during the FS.

2.4.5 EXPOSURE MODELING FOR EACH REMEDIATION SCENARIO

For each remediation scenario in the Sensitivity Analysis, Site-wide risk to UTL receptors was calculated based on a remediation of sediment and soil polygons to PRGs, as outlined in Table 2-2. Three different sediment PRGs were evaluated in the remediation scenarios: the first effects benchmark for benthic invertebrates, half of the first effects benchmark for benthic invertebrates, and the analytical detection limit. A soil background concentration was evaluated as the soil PRG for each scenario. If a background concentration was not found in TCEQ (2006), then a soil concentration that was protective of terrestrial plants or invertebrates was used as the PRG. Sediment and soil remediation goals that were evaluated in the Sensitivity Analysis are provided in Table 2-4.

All concentrations were converted to a wet weight concentration based on the percent water of the remediated sample. The remediated samples were only changed to the PRG value if the actual Site concentration for the sample was higher than the PRG.

For each scenario, Site-wide exposure following remediation was predicted by determining the RME for each COPEC in sediment and soil. The RME was calculated as the 95% UCL of the PRG concentrations in the remediated areas and the sample concentrations in the non-remediated areas. ProUCL version 4.00.02 was used to calculate 95% UCL values for sediment and soil (see Appendix I of the Tier 2 RI Report for a flowchart on the RME process).

For each scenario, UTL receptor exposure to COPECs through ingestion of dietary items was predicted by multiplying the remediation scenario sediment or soil RME by the Site-specific BAF (see Alignment Document for a description of all Site-specific BAFs). A sediment RME and BAF was used for dietary items that likely accumulate COPEC concentrations from sediment exposure. A soil RME and BAF was used for dietary items that likely accumulate COPEC concentrations from soil exposure.

Using these modeled concentrations in sediment, soil, and dietary items following a remediation according to each specified scenario, HQs were generated for all UTL

ROC-COPEC pairs that were retained for the Sensitivity Analysis. See Tier 2 RI for a description of the HQ calculation.

2.4.6 EVALUATION OF REMEDIATION SCENARIO RESULTS

Remediation scenario HQ results were evaluated for reduction in risk to UTL ROCs by measuring the HQs that dropped below one. For each scenario, the percentage of HQs that dropped below one following remediation is listed in Table 2-5 along with the total amount of remediated acres. In addition, the number of HQs that dropped below one, the number of HQs that fell between one and ten, and the number of HQs that were above 10 were compared for each remediation scenario (Table 2-6). The percentage of risk reduction ranged from 0% in the scenario that modeled no remediation (Scenario 1) to 72.06% in the Scenario that modeled remediation of the benthic invertebrate risk areas and all of the Jefferson Canal Spoil Pile (Scenario 10b). The scenario that evaluated complete remediation of the Site (Scenarios 8a, 8b, and 8c) only resulted in a risk reduction of 36.76 – 67.60%, depending on the PRG used in the exposure modeling. The lower risk reduction in Scenarios 8a, 8b, and 8c, compared to the risk reduction in Scenario 10b, occurred because of dietary item concentrations used in the Scenario 10a, 10b, and 10c exposure models. At the request of the EPA, Scenarios 10a, 10b, and 10c, were evaluated with the assumption that remediation of the entire Jefferson Canal Spoil Pile would result in a zero concentration for any dietary item linked to soil exposure (e.g. terrestrial plants, terrestrial insects, and earthworms). This method is in contrast to all other Scenario evaluations in which the soil-linked dietary items were calculated with a Site-specific BAF multiplied by the soil RME. Evaluating these dietary items in this manner resulted in a marked increase in risk reduction, as reflected in Table 2-5 and Table 2-6.

The sediment PRG evaluation between first effects benchmarks, ½ first effects benchmarks, and detection limits generally resulted in a higher risk reduction for sediment remediated to ½ first effects benchmarks. This can be seen in Tables 2-5 and 2-6 by comparing the "b" scenarios (½ first effects benchmarks), to the "a" scenarios (first effects benchmarks) and "c" scenarios (detection limits).

2.4.7 SELECTION OF REMEDIATION SCENARIO

The EPA recommended that risk to benthic invertebrates be the priority when identifying polygons to be addressed in the Sensitivity Analysis. After these polygons were chosen for remediation then exposure to UTL receptors was evaluated based on remediation of those polygons. Remediation scenarios 10a, 10b, 10c, 11a, 11b, and 11c follow this approach, where all sediment samples with an ERM-Q or PEL-Q Category Score > 2 are remediated to a PRG (Table 2-2). Based on this recommendation, the EPA determined that Scenario 10b is the most acceptable scenario moving forward into the FS as this scenario addresses both benthic invertebrate and upper trophic level risk at a PRG that is acceptable. Figure 2-9 shows the Thiessen polygons that are remediated in Scenario 10b.

Scenario 10b is focused on remediating sediment sample areas that likely pose unacceptable risk to benthic invertebrates and also remediating all areas of the Jefferson Canal Spoil Pile. Sediment sample areas with an ERM/PEL-Q category score of 3 (Medium High Priority) or 4 (High Priority) are assumed to be remediated to concentrations at or below half of the first effects sediment benchmarks listed in Table 2-4. Soil is assumed to be remediated to the Soil PRG listed in Table 2-4. Dietary items that were assumed to accumulate COPEC concentrations as a result of contaminated sediment exposure were calculated by multiplying the sediment BAF by the sediment RME. At the request of the EPA, dietary items that were assumed to accumulate COPEC concentrations through soil exposure were set to a zero concentration in the exposure models as an assumption that these items will pose no risk after all of the Jefferson Canal Spoil Pile is remediated to background levels.

2.4.8 SCENARIO 10B RISK ANALYSIS MODIFICATIONS

Results from Scenario 10b indicated acceptable risk levels for most of the COPECs that were evaluated in the Sensitivity Analysis. The following COPECs, pentachlorophenol, aluminum, hexavalent chromium, copper, and manganese, were found to still pose risk to UTL receptors in Remediation Scenario 10b (Table 2-7). EPA recommended that an evaluation be performed on each COPEC found to have unacceptable risk levels with Scenario 10b. These COPECs were assessed for conservative measures that could be contributing to an HQ>1 (source of the highest dose, prey item concentrations calculated with BAFs that are not Site-specific, TRV uncertainty) as well as issues that can help better define the risk to UTL receptors such as bioavailability due to soil chemistry. This assessment was necessary because a remediation of all sediment to detection limits and all soil to background levels (Scenario 8c) resulted in continued risk at the Site (Tables 2-5 and 2-6), indicating that there were a number of conservative measures incorporated into the exposure modeling.

Overly conservative measures in the exposure models can result in unrealistic risk estimates that are then used to develop PCLs and PRGs for ecological receptors. The TCEQ (2005) recommends the use of a LOAEL-based PCL in situations where only conservative exposure assumptions have been used. While TCEQ (2006) has developed some guidelines to follow in determining the most appropriate PCL, the TRRP rule is intentionally silent on how to select a comparative ecological PCL that is bounded by the NOAEL and LOAEL to allow one the flexibility of making this determination. Additionally, if a combination of less conservative and conservative assumptions have been used, it may be appropriate to use a PCL value that is bounded by the upper and lower effect levels but is biased toward the LOAEL bound (TCEQ 2006). An exception to using the average of the NOAEL and LOAEL-based PCLs can also be made in some cases where there is TRV uncertainty. Development of a PCL for consideration as a PRG should take into account the uncertainty of the conservative measures used in the exposure models (TCEQ 2005).

After conservative measures were identified, modifications were made to the exposure models to better define the risk posed by these COPECs. Modifications to these COPEC risk analyses were made according to the recommendations received by the EPA and TCEQ. These modifications included adjustments to the dietary components of the alligator snapping turtle surrogate species (painted turtle), using the $HQ_{[LOAEL]}$ to measure risk, using soil pH levels and AVS/SEM ratios to determine bioavailability, setting non-detect sample concentrations at half detection limits, and using a more appropriate manganese TRV for avian and mammals. COPECs found to have unacceptable risk in Remediation Scenario 10b are described in detail below along with a description of the modifications.

2.4.8.1 PENTACHLOROPHENOL

Pentachlorophenol was found to have unacceptable risk levels in the raccoon and the painted turtle in Remediation Scenario 10b (raccoon $HQ_{[GMATC]}$ = 1.57, painted turtle $HQ_{[NOAEL]}$ = 2.10).

A large majority of the pentachlorophenol total daily dose (TDD) in raccoons was from ingestion of prey items, specifically mollusks (97.44% of TDD). The mollusk BAF was calculated with a literature-derived sediment-to-mollusk BAF, therefore not representative of realistic bioaccumulation at the Site. A Site-specific BAF value was not included in the exposure models because mollusk samples were not collected at the Site. This mollusk BAF (3308.8) was based on a recommended bioconcentration factor (BCF) value from USEPA (1999) multiplied by the food chain multiplier (FCM). The recommended BCF was calculated using a regression equation (log BCF = 0.819 x log K_{ow} - 1.146) due to the lack of available empirical data (USEPA 1999). According to USEPA (1995), a measured baseline BAF for an organic or inorganic chemical derived from a field study of acceptable quality is the most preferred method for deriving baseline BAFs. Conversely, deriving a baseline BAF from a predicted baseline BAF for an organic chemical derived from a K_{ow} of acceptable quality and a FCM is the least preferred method. There is concern that the TDD of the raccoon is overly conservative due to the mollusk concentration being calculated with a non-empirically derived BAF. Using a non-empirically derived BAF to calculate concentrations that contribute the largest exposure source to the raccoon can be considered an overly conservative exposure assumption. This assumption supports the use of a LOAEL-based HQ for the raccoon (TCEQ 2005), which has a value less than one ($HQ_{[LOAEL]}$ = 0.70) and indicates acceptable risk levels for the raccoon in Scenario 10b.

The painted turtle was selected as a surrogate species for the state-threatened alligator snapping turtle due to the exposure information that is available for the surrogate species. However, there is considerable difference in the diet of these two species, with a majority carnivorous diet occurring in the alligator snapping turtle and a majority herbivorous diet occurring in the painted turtle. As dietary dose in the alligator snapping turtle is most likely to be attributable to fish, the dietary proportions were modified in the painted turtle exposure model to 100% fish. This change in dietary exposure source resulted in an $HQ_{[NOAEL]}$ = 0.06, indicating acceptable risk levels for the alligator snapping turtle (painted turtle as surrogate) in Scenario 10b.

2.4.8.2 <u>ALUMINUM</u>

Aluminum exposure resulted in unacceptable risk levels following a remediation according to Scenario 10b. The following HQs indicated unacceptable risk: american robin $HQ_{[GMATC}$ = 3.04, short-tailed shrew $HQ_{[GMATC]}$ = 1.11, belted kingfisher $HQ_{[GMATC]}$ = 32.78, marsh wren $HQ_{[GMATC]}$ = 11.39, spotted sandpiper $HQ_{[GMATC]}$ = 29.15, wood stork $HQ_{[NOAEL]}$ = 1.51, bullfrog $HQ_{[GMATC]}$ = 1.54, painted turtle $HQ_{[NOAEL]}$ = 1.28. While ingesting these concentrations did result in a HQ>1, it can be assumed that aluminum is not bioavailable to the receptors as most pH readings in the soil samples were above 7.0. This is based on the Eco-SSL for Aluminum (USEPA 2003) that states the following:

> *Because the measurement of total aluminum in soils is not considered suitable or reliable for the prediction of potential toxicity and bioaccumulation, an alternative procedure is recommended for screening aluminum in soils. The procedure is intended as a practical approach for determining if aluminum in Site soils could pose a potential risk to ecological receptors. This alternative procedure replaces the derivation of numeric Eco-SSL values for aluminum. Potential ecological risks associated with aluminum are identified based on the measured soil pH. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5 (EPA 2003).*

Soil pH levels at the Site indicate aluminum is not bioavailable to the receptors (USEPA 2003), therefore this COPEC is assumed to pose acceptable risk levels to the UTL receptors in Scenario 10b and under Site conditions. Based on these bioavailability factors, it was determined that aluminum did need to be carried forward in the FS.

2.4.8.3 HEXAVALENT CHROMIUM

Exposure to hexavalent chromium resulted in unacceptable risk levels in Remediation Scenario 10b. The following HQs indicated unacceptable risk: belted kingfisher $HQ_{[GMATC]}$ = 4.23, spotted sandpiper $HQ_{[GMATC]}$ = 1.01, bullfrog $HQ_{[GMATC]}$ = 2.69, painted turtle $HQ_{[NOAEL]}$ = 1.04.

All receptors found to be at risk from hexavalent chromium exposure in Scenario 10b were receiving the largest source of risk from dietary items. Risk drivers to the belted kingfisher were consumption of fish (96.12% of TDD) and crustaceans (3.81% of TDD). Risk drivers to the spotted sandpiper were also consumption of fish (45.59% of TDD) and crustaceans (45.59% of TDD). The bullfrog was getting the largest daily dose from fish (78.64% of TDD) and insects (11.01% of TDD). Risk drivers to the painted turtle were consumption of fish (9.35% of TDD), insects (64.48% of TDD), vegetation (16.03% of TDD) and crustaceans (9.35% of TDD).

Site-specific BAFs were not able to be calculated for fish, crustaceans, or mollusk dietary items due to analytical rejections of the tissue. Due to this lack of Site-specific data, the dietary items RMEs were calculated with a literature-derived BAF. By not using a Site-specific BAF for these dietary items, it is likely the RMEs are not accurately predicting bioaccumulation of chromium VI in dietary items at the Site. This could lead to an overestimation of the predicted concentration in fish, crustaceans, and mollusks.

Additionally, UTL receptors that consume aquatic species may have an overestimated risk as biomagnification of chromium in aquatic food webs is reported to be insignificant (Agency for Toxic Substances and Disease Registry [ATSDR], 1993). The toxic effects of chromium are primarily found at the lower trophic levels. Chromium has been found to bioaccumulate in algae, other aquatic vegetation, and invertebrates, but it does not biomagnify. Further, hexavalent chromium is readily converted to trivalent chromium in animals, which appears to protect higher organisms from the effects of low level exposures (Eisler 1986).

TRV uncertainty and conservatism were found to be potentially an overly conservative factor in the HQ calculations. As no data were found regarding songbirds and passerines, the chicken TRV was used to extrapolate the TRV for the belted kingfisher and the spotted sandpiper by dividing by 5 to account for inter-taxon variability. The chicken TRV was also used to extrapolate the TRV for the bullfrog and painted turtle due to lack of exposure data. The chicken TRV was divided by an uncertainty factor of 10 to account for interclass variation. Using an uncertainty factor due to extrapolation between species and classes can result in an overly conservative TRV.

In addition to the use of literature-derived BAFs, the dietary item concentrations could also be inaccurate due to the sediment RME used in the calculation. The sediment RME used in the Sensitivity Analysis was not based on all sediment samples at the Site because 19 of the sediment samples (17% of the total) collected at the Site were rejected for analytical testing. Of the samples that were not rejected, only 12 percent had detectable concentrations. Therefore, there is concern that the sediment RME is based not only on insufficient data but also on a large majority of detection limits. Sediment RMEs were calculated using half detection limits for the samples with non-detectable concentrations at the recommendation of the EPA due to the concern of high detection limits driving the sediment RME. The modified sediment RME did result in acceptable risk levels at the Site. Risk calculations were as follows: belted kingfisher $HQ_{[GMATC]}$ = 0.85, spotted sandpiper $HQ_{[GMATC]}$ = 0.98, and bullfrog $HQ_{[GMATC]}$ = 0.64. As dietary dose in the alligator snapping turtle is most likely to be attributable to fish, the dietary proportions were modified in the painted turtle exposure model to 100% fish. This change in dietary exposure source resulted in acceptable risk levels ($HQ_{[NOAEL]}$ = 0.62).

The modified exposure factors (diet in the painted turtle model and half detection limits for sediment non-detects in the spotted sandpiper, belted kingfisher, and bullfrog models) resulted in risk calculations that indicate acceptable risk levels at the Site for these receptors following remediation according to Scenario 10b. A lack of significant biomagnification in the UTL receptors consuming aquatic species indicates acceptable risk levels for these receptors as well.

2.4.8.4 COPPER

Exposure to copper resulted in unacceptable risk levels following remediation according to scenario 10b. The following HQs indicate unacceptable risk: belted kingfisher $HQ_{[GMATC]}$ = 1.39 and spotted sandpiper $HQ_{[GMATC]}$ = 1.39. Risk drivers in the belted kingfisher were mainly from food ingestion (37.98% of TDD from fish, 4.98% of TDD from amphibians, and 56.99% of TDD from crustaceans). Risk drivers in the spotted sandpiper were due to ingestion of fish (15.01% of TDD), crustaceans (72.90% of TDD), and sediment (12.02% of TDD).

Of the 113 surface sediment samples evaluated, 12 had total SEM/AVS concentrations greater than 1.0. The freshwater samples included one location in Jefferson Canal (JC-13). The saltwater samples included one location in the Gulf States Utility Canal (GSUC-10), six locations in Molasses Bayou (MB-2, MB-12, MB-13, MB-23, MB-59, MB-63), three locations in Former Star Lake (SL-6, SL-7, SL-9), and one location in Star Lake Canal (SLC-6). Seven of these sediment samples have an ERM/PEL-Q Score >2, therefore will be remediated in Scenario 10b. The remaining 101 samples had total SEM values less than their AVS concentrations indicating that these metals in the sediment pore water are precipitated as a metal sulfide and are not likely to be bioavailable. It can be assumed that metal concentrations will decrease in the remediated sample areas, leaving only five sediment samples at the Site with bioavailable copper concentrations.

Risk calculations that do not take into account the presence of metal sulfides at the Site likely overestimate risk to the receptors as copper concentrations are not largely bioavailable. This conservatism in the exposure models warrants the use of a LOAEL-based HQ for risk determination. The $HQ_{[LOAEL]}$ for the belted kingfisher and spotted sandpiper ($HQ_{[LOAEL]}$ = 0.622 for both species) indicates acceptable risk levels for these species exposed to Site-wide concentrations of copper following remediation according to Scenario 10b.

2.4.8.5 MANGANESE

Exposure to manganese resulted in unacceptable risk in Remediation Scenario 10b. The following HQs indicated unacceptable risk: muskrat $HQ_{[GMATC]}$ = 2.97, belted kingfisher $HQ_{[GMATC]}$ = 1.49, painted turtle $HQ_{[NOAEL]}$ = 8.02. Risk to the muskrat was largely driven by vegetation in the diet (99.98% of TDD). Risk from manganese exposure in the belted kingfisher was also due to dietary items, but drivers were crustaceans (90.25%) and fish (8.43% of TDD). The painted turtle was determined to be at risk due to ingestion of vegetation (43.12% of TDD) and crustaceans (50.49% of TDD).

TRV uncertainty was found to be a possible contributor to the risk calculations for manganese. The belted kingfisher TRV is based on a 6-week (approximate test duration) value of 7.3 mg/kg-bw/day for guinea fowl exposed to manganese sulfate (Offiong and Abed 1980). This study was designed to assess the nutritional deficiencies of manganese and the maximum dose examined significantly improved the fertility, hatchability, and embryos of guinea fowl compared to controls. Therefore, the maximum dose examined (70 mg/kg feed; 7.3 mg/kg-bw/day) represents a required dose for successful reproduction and is likely considerably lower than a true NOAEL. As such, this value should be considered extremely conservative. . .

No data were found on reptile or amphibian exposure to manganese, therefore the avian TRV was used for extrapolation by dividing by an uncertainty factor of 10 to account for interclass variation, resulting in a TRV of 0.73 mg/kg-bw/day. As the avian TRV is likely an overly conservative value, adding an additional uncertainty factor for extrapolation to reptiles and amphibians is also very likely to be an overly conservative measure of risk.

TRVs previously used in the exposure models for the muskrat and belted kingfisher were replaced by TRVs for mammalian and avian species, respectively, found in the Eco-SSL for Manganese (EPA 2007). The avian TRV is based on the geometric mean of the reported NOAELs for growth and reproduction in 21 studies approved according to Eco-SSL guidance. The geometric mean of these NOAEL values for reproduction and growth was calculated at 179 mg manganese/kg bw/day. Fifty-eight studies were approved according to Eco-SSL guidance for use in the derivation of a mammalian TRV.

The geometric mean of the 58 reported NOAELs for reproduction and growth was calculated at 51.5 mg manganese/ kg bw/day. Using these less conservative TRVs, manganese exposure to the muskrat and belted kingfisher was determined to be at acceptable risk levels (muskrat $HQ_{[GMACT]}$ = 0.51, belted kingfisher $HQ_{[GMACT]}$ = 0.061) following remediation according to Scenario 10b).

As dietary dose in the alligator snapping turtle is likely to come mostly from fish, the dietary proportions were modified in the painted turtle exposure model to 100% fish. This change in dietary exposure source resulted in acceptable risk levels ($HQ_{[NOAEL]}$ = 0.34).

2.4.9 CONCLUSIONS

Remediation scenarios in the Sensitivity Analysis were chosen for their potential contribution to a reduction in risk to UTL receptors and/or benthic invertebrates. Risk calculations for COPECs showing unacceptable risk as a result of conservative measures were modified to provide a more realistic prediction of risk to UTL receptors following remediation. These modifications included adjustments to the dietary components of the alligator snapping turtle surrogate species (painted turtle), using the $HQ_{[LOAEL]}$ to measure risk, using soil pH levels and AVS/SEM ratios to determine bioavailability, setting non-detect sample concentrations at half detection limits, and using a more appropriate manganese TRV for avian and mammals. With these modifications, all COPECs were found to pose acceptable risk levels following remediation based on Scenario 10b (Table 2-8). Aluminum was determined to pose acceptable risk levels at the Site for all ROCs based on bioavailability; therefore, aluminum was not carried forward in the FS. Scenario 10b was recommended by the EPA, TCEQ, and trustees as the remediation scenario to be evaluated in the FS.

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The following sections present the RAOs, Applicable or Relevant and Appropriate Requirements (ARARs), COCs, and PRG, and general response actions for the FS. This section also includes the screening of potential technology types and process options against effectiveness, implementability, and cost.

3.1 REMEDIAL ACTION OBJECTIVES

Identification of RAOs is the first step in the CERCLA FS process following the RI. RAOs specify the COCs, medium where COCs were found, exposure pathways, and goals that will take into account a myriad of scenarios to achieve the final objective. The RAOs were developed based on a conglomeration of information presented in the Tier 1 and Tier 2 RI documents and the Alignment document. In addition to these documents, the RAOs were written in accordance with the Site chemical-, location-, and action-specific ARARs that are discussed in Section 3.1.1. In the BERA, data and modeling validated the risk to benthic organisms and upper trophic level receptors while eliminating or invalidating the risk to human receptors as it pertains to this Site. The conclusion and focus of the remediation activity was determined to be concentrated on the ecological exposure risk to benthic organisms and upper trophic level receptors as it was deemed to be an unacceptable risk of exposure to toxic chemicals and metals found in the sediment and soil in which these organisms live.

The RAOs for the Site follow:

Ecological

- Reduce to acceptable levels of toxicity to benthic invertebrates and upper trophic level receptors at the Site from direct contact with COCs in the sediment (A detailed discussion of the COCs is provided in Section 3.1.2 below)
- Reduce to acceptable levels of toxicity to upper trophic level receptors at the Site from direct contact with COCs in the soil of the Jefferson Canal Spoil Pile (A detailed discussion of the COCs is provided in Section 3.1.2 below)

Human Health

- The HHRA did not identify any potential risk from COPCs for human receptors that may utilize the Site. Therefore, no RAOs were needed or developed for the protection of human health.

3.1.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

As defined by CERCLA Section 121, specified remedial actions shall be protective of human health and the environment. ARARs and to-be-considered materials (TBC) have been used to specify the level of protection of human health and the environment.

ARARs are requirements established under Federal or State environmental laws that are either "applicable" or "relevant and appropriate".

Applicable requirements are remediation standards, standards of control, and other substantive environmental protection requirements, criteria, or restrictions that address the specific situation at a CERCLA site regarding the hazardous substance, chemical, remedial actions, location, or other characteristics of the site.

Relevant and appropriate requirements address problems or situations sufficiently similar although not specific to the characteristics at the site. In situations that a requirement is relevant but not appropriate due to specific characteristics of the Site, the requirement is not an ARAR for the Site.

A two-step process is used to identify ARARs on a Site-specific basis. The first step in the process is determining whether the requirement is applicable. If the requirement is not applicable, then the second step in the process is to determine whether the requirement is both relevant and appropriate.

TBCs are guidance, criteria, and advisories issued by the Federal or State government that are not publicized or legally binding. Although TBCs do not have the status of potential ARARs, TBCs may be useful in determining the required level of cleanup for protection of human health and the environment.

Based on CERCLA guidance, ARARs were classified into three types during the FS.

- Chemical-specific requirements – These requirements define acceptable concentrations of a chemical that may be present in the environment or released to the environment (Table 3-1).
- Location-specific requirements – These requirements restrict concentrations of hazardous material and remediation activities based on the specific site location. These locations include sensitive or hazard-prone areas such as active fault zones, wildlife habitat and flood plains (Table 3-2).
- Action-specific requirements – These requirements control activities and technologies selected relative to remediating the Site (Table 3-3).

ARARs will be one of the nine criteria that are used to evaluate remedial alternatives at the Site. Section 121(d) of CERCLA stipulates that remedial actions instituted under the Superfund program comply with ARARs. Consideration must also be given to relevant information that, while not legally binding, is collectively referred to as to be considered (TBC) information. TBCs may or may not be promulgated standards and not legally enforceable but may contribute to the development and implementation of effective and protective remedial alternatives.

The ARARs that were identified as being applicable for the Site RI/FS include CERCLA, Texas Commission on Environmental Quality, the Toxic Substances Control Act (TSCA), the Resource Conservation Recovery Act (RCRA), the Occupational Safety and Health Administration (OSHA), Hazardous Materials Transportation Act, Floodplain Management, Protection of Wetlands, National Historical Preservation Act, Endangered Species Act of 1973, Rivers and Harbors Act of 1899, and the Fish and Wildlife Coordination Act requirements.

As summarized in Table 3-1, Table 3-2, and Table 3-3, the ARARs are defined and classified into categories based on chemical-specific, location-specific, and action-specific requirements.

3.1.2 CONSTITUENTS OF CONCERN

Physical and chemical properties, environmental fate and transport, as well as toxicity, differ among the COCs for which PRGs have been developed. The purpose of this section is to summarize the characteristics of these COCs and their general toxicity concerns.

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

The compounds 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, ideno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene belong to the group of compounds known as PAHs and are defined as hydrocarbons containing two or more aromatic rings. PAHs are released into the environment from both natural and manmade sources and are common constituents of petroleum hydrocarbon mixtures such as diesel, motor oil, and asphalt.

In general, PAHs have low water solubility and may increasingly adsorb to soil, sediment, or suspended solid particles within water with increasing organic carbon content. Adsorption is also directly dependent on particle size. Smaller particles with higher surface area to volume ratios are more efficient at adsorbing PAHs. PAH compounds are more mobile in systems with small amounts of organic carbon. Adsorption to soil particles is the primary process responsible for the removal of PAHs from aqueous systems. The Henry's Law constant (K_H) ranges from 10^{-4} to 10^{-8} atmospheres per cubic meter per mole (atm-m^3/mol) for individual PAHs. The soil organic carbon water partition coefficient K_{oc} values for the high molecular weight PAHs are in the range of 10^5 to 10^6, which indicates a strong tendency to adsorb to organic carbon present in soil and sediment. The high adsorption potential of PAHs to soil and sediment explains the frequency with which PAHs were detected in soil and sediment samples at the Site.

Toxicity

The toxicity of PAHs is generally expressed relative to the toxicity of benzo(a)pyrene. In addition to benzo(a)pyrene, six other PAHs, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, chrysene, and ideno(1,2,3-cd)pyrene are classified by the EPA as probable human carcinogens. These other compounds have been estimated to be approximately 1 to 1,000 times less carcinogenic than benzo(a)pyrene, therefore the toxicological information for benzo(a)pyrene is discussed herein.

Benzo(a)pyrene is readily absorbed after inhalation, oral, and dermal routes of exposure. The metabolism of benzo(a)pyrene is complex and includes the formation of benzo(a)pyrene-7,8-diol-9,10-epoxide which is classified as a proposed carcinogen by the EPA. No data is available on the noncarcinogenic effects of benzo(a)pyrene in humans.

Numerous epidemiologic studies have shown a clear association between exposures to various mixtures (e.g., coke oven emissions, roofing tar emissions, and cigarette smoke) of PAHs containing benzo(a)pyrene and an increased risk of lung cancer and other tumors. However, each of the mixtures also contained other potentially carcinogenic PAHs, therefore, it is not possible to evaluate the contribution of benzo(a)pyrene alone to the carcinogenity of these mixtures.

POLYCHLORINATED BIPHENYLS (PCBS)

PCBs are a class of organic compounds with 1 to 10 chlorine atoms attached to biphenyl, which is a molecule composed of two benzene rings. PCBs are, in general, highly resistant to chemical or biological transformation. They exhibit a relatively high degree of persistence in the environment and biomagnification in aquatic and terrestrial food chains and are thus treated as a special class of compounds. PCBs are insoluble in water and will partition from the water column and adsorb strongly to sediments and suspended matter. The solubility of PCBs decreases with increases in chlorination. The organic carbon partition coefficient is higher for the higher chlorinated isomers, which indicates they will sorb more strongly. PCBs volatilize from water. PCBs of the higher chlorinated biphenyl groups (e.g., higher than the tetrachlorinated biphenyls) do not significantly biodegrade in soils, especially those with high organic carbon content. In sediment, there appears to be a potential for anaerobic biodegradation, which is determined by congener reactivity. Biomagnification via impacted food is the principle route of uptake for low water-soluble compounds like PCBs. The major source to plant vegetation is through contact with volatilized PCBs in the air.

Toxicity

PCBs have been classified by the EPA as probable human carcinogens. The toxicity of PCBs increases with length of exposure and position of the exposed species in the food chain. PCBs can affect mortality, can have adverse effects on reproduction, and can cause behavioral changes in terrestrial wildlife. In aquatic systems, PCBs can affect reproduction and endocrine function in fish and semi-aquatic birds and mammals, primarily through interference of the aryl hydrocarbon receptor (AHR). The primary effects of PCBs in aquatic systems occur at the higher trophic levels of the food web through uptake by benthic invertebrates and bioconcentration because benthic invertebrates lack the AHR.

The toxicity of the various PCB mixtures is also dependent on their composition. The coplanar PCBs are known as non-ortho PCBs because they are not substituted at the ring positions ortho to (next to) the other ring, (i.e., PCB congeners 77, 126, 169, etc.). The non-ortho PCBs tend to have dioxin-like properties, and generally are considered among the most toxic congeners. Because of this property, the toxicity of these congeners is related to that of 2,3,7,8-tetrachlorodibenzo[p]dioxin (TCDD) through the use of toxic equivalency factors (TEFs), where the more toxic PCB congeners are assigned higher TEF values. TCDD is assigned a TEF of 1.

METALS

ANTIMONY

Antimony is a silvery-white metal that is found in the earth's crust. Antimony ores are mined and then mixed with other metals to form antimony alloys or combined with oxygen to form antimony oxide. The United States currently mines very little antimony, and therefore it is brought in from other countries for processing. However, there are companies in the United States that produce antimony as a by-product of smelting lead and other metals. Antimony is not used alone because it breaks easily, but when mixed into alloys, it is used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, and pewter. Antimony oxide is added to textiles and plastics to prevent them from catching fire. It is also used in paints, ceramics, and fireworks, and as enamels for plastics, metal, and glass. Antimony is released to the environment from natural sources and from industry. Antimony also enters the environment during the mining and processing of its ores and in the production of antimony metal, alloys, antimony oxide, and combinations of antimony with other substances. Small amounts of antimony are also released into the environment by incinerators and coal-burning power plants. The antimony that comes out of the smoke stacks of coal-burning power plants is attached to very small particles that settle to the ground or are washed out of the air by rain. Antimony cannot be destroyed in the environment; it can only change its form or become attached to or separated from particles. Most antimony will end up in the soil or sediment, where it attaches strongly to particles that contain iron, manganese, or aluminum (ATSDR 1992).

Toxicity

Exposure to antimony at high levels can result in a variety of adverse health effects. Breathing high levels for a long time can irritate your eyes and lungs, and cause heart and lung problems, stomach pain, diarrhea, vomiting, and stomach ulcers. In short-term studies, animals that breathed very high levels of antimony died. Animals that breathed high levels of antimony had lung, heart, liver, and kidney damage. In long-term studies, animals that breathed very low levels of antimony had eye irritation, hair loss, lung damage, and heart problems. In addition, problems with fertility were also noted. In animal studies, problems with fertility have been seen when rats breathed very high levels of antimony for a few months. Long-term animal studies have reported liver damage and blood changes when animals ingested antimony. Antimony can irritate the skin if it is left on it (ATSDR 1992). It is known that ingesting large doses of antimony can cause vomiting, but other effects are unknown.

Antimony does not appear to bioconcentrated appreciably in fish and aquatic organisms. Uptake from soil is minor and appears to be correlated with the amount of available antimony (that which is soluble or easily exchangeable). Antimony does not biomagnify from lower to higher trophic levels in the food chain (ATSDR 1992).

ARSENIC

Arsenic is a naturally occurring element that is widely distributed in the earth's crust. Arsenic is classified chemically as a metalloid, having both properties of metals and nonmetals. It has oxidation states of +1, +2, +3, +5, and -3. Elemental arsenic is a steel grey solid material; however, arsenic is usually found in the environment combined with other elements such as oxygen, chlorine, and sulfur. Arsenic combined with carbon and hydrogen is referred to as organic arsenic.

Until December 31, 2003, inorganic arsenic compounds were primarily used to preserve wood. Copper chromated arsenic (CCA) was used to make "pressure-treated" lumber. CCA is no longer used in the U.S. for residential purposes. In the past, inorganic arsenic compounds were predominantly used as pesticides, primarily on cotton fields and in orchards. Inorganic arsenic compounds are no longer used in agriculture. However, some organic arsenic compounds are still used in pesticides.

Arsenic cannot be destroyed in the environment; itt can only change its form or become attached to or separated from particles. Arsenic may be transported by wind or in runoff or may leach into subsurface soil. Arsenic is largely immobile in soil; therefore, it tends to concentrate and remain in the upper soil layers. Transport and partitioning of arsenic in water depends upon the chemical form. Soluble forms move with the water and may be carried long distances. Arsenic may be adsorbed from water onto sediment or soil particles.

Toxicity

The Department of Health and Human Services (DHHS) and the EPA have determined that inorganic arsenic is a known human carcinogen. Inhalation is the predominant occupational exposure route. For the general population, diet is the largest source of exposure. Dermal uptake is a minor route of exposure.

Inhalation of inorganic arsenic may cause respiratory irritation, nausea, skin effects, and increased risk of lung cancer. Acute oral exposure to inorganic arsenic may cause nausea, vomiting, diarrhea, cardiovascular effects, and encephalopathy. Long-term exposure to low levels of arsenic may cause dermal effects and a peripheral neuropathy characterized by numbness in the hands and feet. There may also be increased risk of skin, bladder, and lung cancer. In most species, including humans, ingested organic arsenic compounds undergo limited metabolism, do not readily enter the cell, and are primarily excreted unchanged in urine.

CADMIUM

Cadmium is a natural metal in the earth's crust and is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide). Soils and rocks, including coal and mineral fertilizers, usually contain some cadmium. Most cadmium used in the United States is extracted during the production of other metals like zinc, lead, and copper. Cadmium does not corrode easily and has many uses, including batteries, pigments, metal coatings, electroplating and plastics. Cadmium is also found in some industrial paints and may represent a hazard when sprayed. Cadmium emits a characteristic brown fume (CdO) upon heating, which is relatively non-irritating, and thus does not alarm the exposed individual. Several deaths from acute exposure have occurred among welders who have unsuspectingly welded on cadmium-containing alloys or worked with silver solders (ATSDR 2008).

In the environment, cadmium enters soil, water, and air from mining, industry, and burning coal and household wastes. Cadmium can change forms in the environment, but does not break down and airborne particles can enter the ground and water. In the ground cadmium binds strongly to soil particles and some forms can dissolve. Thus, fish, plants, and animals can take up cadmium from their environments (ATSDR 2008).

Toxicity

Cadmium is an extremely toxic metal commonly found in industrial workplaces, particularly where any ore is being processed or smelted. In addition to industrial exposure, low levels of cadmium are found in many foods (particularly shellfish, liver and kidney meats) as well as cigarette smoke. Breathing high levels of cadmium can severely damage the lungs. Eating food or drinking water with very high levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels of cadmium in air, food, or water leads to a buildup of cadmium in the kidneys and possibly lead to kidney disease. Other long-term effects are lung damage and fragile bones. DHHS has determined that cadmium and cadmium compounds are known human carcinogens (ATSDR 2008).

A few studies in animals indicate that younger animals absorb more cadmium than adults and that the young are more susceptible than adults to a loss of bone and decreased bone strength from exposure to cadmium. It is unknown whether cadmium causes birth defects in humans, however offspring of animals exposed to high levels of cadmium during pregnancy had changes in behavior and learning ability. There is also some information from animal studies that high enough exposures to cadmium before birth can reduce body weight and affect the skeleton in the developing young (ATSDR 2008).

CHROMIUM

Environmental concentrations of chromium are attributable to both natural and anthropogenic sources, with the largest contribution coming from industrial releases. The primary contributing industries include metal processing, tannery facilities, chromate production, stainless steel welding, and ferrochrome and chrome pigment production. The estimated atmospheric chromium levels in the United States urban and nonurban areas typically reflect mean total chromium concentrations ranging from 5 to 525 nanograms per cubic meter (ng/m^{3}). Chromium concentrations in United States fresh waters typically range from <1 to 30 micrograms per liter (μg/L), with a median value of 10 μg/L.

Chromium concentrations in typical United States drinking water supplies range from 0.2 to 35 μg/L; however, most supplies in the United States contain less than 5 μg/L. Specifically related to chromium VI, recent monitoring data from California, indicated that 86 percent of drinking water supplies tested had chromium VI levels below 10 μg/L. Total chromium in U.S. soils ranges from 1 to 2,000 milligrams per kilogram (mg/kg), with a mean concentration of 37 mg/kg. The mean total chromium level in ocean water is 0.3 μg/L (ATSDR 2008).

Toxicity

The primary adverse health effects associated with chromium VI exposure are respiratory, gastrointestinal, immunological, hematological, reproductive, and developmental in nature. In addition, direct contact with chromium VI may result in dermal and ocular irritation. Available dose-response data in humans and animals suggest that the most sensitive noncancer effects of chromium VI compounds are respiratory (nasal and lung irritation, altered pulmonary function), gastrointestinal (irritation, ulceration and non-neoplastic lesions of the stomach and small intestine), hematological (microcytic, hypochromic anemia), and reproductive (effects on male reproductive organs, including decreased sperm count and histopathological change to the epididymis) (ATSDR 2008).

The primary effects of chromium III compounds are respiratory and immunological in nature. Respiratory effects appear to be portal-of-entry effects for inhalation exposure. Similarly, chromium allergic dermatitis, which is the major immunological effect of chromium III, typically results from dermal contact in sensitized individuals. The initial sensitization, however, may result from one or more of the following exposure routes alone or in combination: inhalation, oral, or dermal exposure. Conflicting results have been reported from developmental and reproductive animal studies of chromium III compounds. These results do, however, provide evidence of adverse effects on the developing and adult reproductive system. No evidence of developmental or reproductive effects of chromium III in humans has been identified. Based on results of chronic-duration oral studies in animals, chromium III compounds (chromium acetate, chromium chloride, chromium nicotinate, chromium oxide, chromium picolinate) do not appear to produce gastrointestinal, hematological, hepatic, renal, cardiovascular, endocrine, or musculoskeletal effects (ATSDR 2008).

COPPER

Copper occurs naturally throughout the environment, in rocks, soil, water, and air and is an essential element in plants, animals, and humans. Copper is used to treat plant diseases, for water treatment and as a preservative in wood, leather, and fabrics. Copper is also used to make products like wire, plumbing pipes, and sheet metal. United States pennies made before 1982 are made of copper while those after 1982 are only coated with copper.

Copper is released into the environment by mining, farming, and manufacturing operations and through wastewater releases into lakes and rivers. Natural sources of copper releases include windblown dusts, decaying vegetation, forest fires, and volcanoes. Once in the environment, copper usually attaches to particles made of organic matter, clay, soil, or sand, and it does not breakdown (ATSDR 2004).

Toxicity

Copper exposure can occur through breathing air, drinking water, or eating foods containing copper. Drinking water in homes can contain high levels of copper if the home has copper pipes and acidic water. In addition, lakes and rivers that have been treated with copper compounds to control algae or receive cooling water from power plants can have high levels of copper. Exposure through the soil typically occurs in areas near copper smelting plants. Copper is primarily ingested via copper-containing fungicides or in areas near copper mines or copper processing plants (ATSDR 2004).

While small amounts of copper are ingested daily and are essential for good health, high levels can be harmful. Breathing high levels of copper can cause irritation of your nose and throat and ingesting high levels of copper can cause nausea, vomiting, and diarrhea. Very-high doses of copper can cause damage to your liver and kidneys, and can even cause death. It is unknown whether copper can cause cancer in humans and the EPA has determined that copper is not classifiable as to human carcinogenicity. Further, it is unknown if copper causes birth defects or other developmental defects though studies in animals suggest a potential decrease in fetal growth. There is a small percentage of infants and children who are unusually sensitive to copper and studies in animals indicate that young children may have more severe, albeit the same, effects than adults but this is unproven in humans (ATSDR 2004).

LEAD

Lead is a naturally occurring metal found in the earth's crust, typically in the range of 15–20 mg/kg. In comparison to aluminum and iron, the two most abundant metals in the earth, lead is relatively uncommon. Lead is rarely found in its elemental state and most commonly occurs in the form of its +2 oxidation state in various ores. The most important lead containing ores include the following: galena (PbS), anglesite ($PbSO_4$), and cerussite ($PbCO_3$). The world's lead reserves, over one third of which are located in North America, are estimated at $7.1x10^7$ tons. An observed increase in environmental lead levels, not associated with ore deposits, over the past three centuries is attributable to human activity. Lead exposure is common in humans as a result of the widespread use of this metal. The largest ongoing industrial use of lead is the production of lead batteries, which are largely used in the automobile industry. Other uses include the production of lead alloys, soldering materials, shielding for x-ray machines, and in the manufacture of corrosion and acid resistant building materials (ATSDR 2007).

Toxicity

The health effects of lead on human health are well documented. The toxicity of lead to humans has been known for centuries. Only during the past few decades, however, has it been established that exposure resulting in relatively low levels of lead in blood (e.g., <20 micrograms per deciliter (µg/dL) is associated with adverse effects in the developing organism. Most modern data regarding lead toxicity originates from occupational studies covering a variety of industries and also from studies of the general population, encompassing both adults and children. The most sensitive targets for lead toxicity include: the developing nervous system, the hematological and cardiovascular systems, and the kidneys. Due to the multi-modes of action of lead in biological systems, however, lead has the potential to affect any system or organ in the body (ATSDR 2007).

MANGANESE

Manganese is a naturally occurring element, the twelfth most abundant, and is also an essential nutrient. Manganese comprises approximately 0.1 percent of the earth's crust and is the fifth most abundant metal. Manganese does not naturally occur in its elemental form, but mainly occurs as oxides, carbonates, and silicates in over 100 minerals. Pyrolusite (manganese dioxide) is the most common naturally-occurring form of manganese. Manganese is required for the urea cycle, as well as for the formation of healthy cartilage and bone. It also aids in the maintenance of mitochondria and the production of glucose and plays a key role in wound-healing.

Manganese exists in both inorganic and organic forms. Inorganic manganese is used as an essential ingredient in steel. It is also used in the production of dry-cell batteries, glass, and fireworks, as well as in chemical manufacturing, in the leather and textile industries, and as a fertilizer. Organic manganese is commonly used in fungicides, fuel-oil additives, smoke inhibitors, as an anti-knock additive in gasoline, and as a medical imaging agent. Natural erosion and soil creation processes result in average manganese soil concentrations of 40 to 900 mg/kg in the United States. Naturally occurring manganese levels in soil result in varying manganese concentrations found in vegetables and animal foods. The most important source of atmospheric manganese is the air erosion of dusts or soils. The mean ambient air concentration of manganese in the United States is 0.02 µg/m^3; ambient levels near industrial sources, however, can range from 0.22 to 0.3 µg/m^3. Release of manganese into waterways mainly occurs through the erosion of rocks and soils, mining activities, and industrial waste, or by the leaching of manganese from anthropogenic materials discarded in landfills or soil, such as dry-cell batteries. United States surface waters exhibit a median manganese level of 16 µg/L, with 99th percentile concentrations of 400 to 800 µg/L. Groundwater in the United States contains median manganese levels of 5 to 150 µg/L, with the 99th percentile at 2,900 or 5,600 µg/L in rural or urban areas, respectively (ATSDR 2008).

Toxicity

While manganese is a necessary nutrient, exposure to high levels of manganese results in toxicity. Reports of adverse health effects in humans attributable to manganese primarily stem from inhalation exposures in occupational settings. Inhalation of manganese sometimes results in its direct transport to the brain instead of being metabolized by the liver. Manganese toxicity may manifest slowly with symptoms becoming noticeable over a period of months and years. Manganese toxicity has been known to result in a permanent neurological disorder called manganism, the symptoms of which include tremors, difficulty walking, and spasms of the facial muscles. Some studies report an association between manganese inhalation and adverse cognitive effects, including difficulty with concentration and memory problems. Acute or intermediate exposure to excess manganese is also known to affect the respiratory system. Inhalation exposure to high levels of manganese dusts can cause an inflammatory response and ultimately an impaired lung function. Lung toxicity is also manifested as an increased susceptibility to and can result in manganic pneumonia. Many studies report significant health effects, most prominently observed in children, resulting from oral exposure to manganese, especially from contaminated water sources. These effects are similar to those linked to inhalation exposure. A threshold level at which manganese exposure produces neurological effects in humans has not yet been established. There is also indirect evidence that reproductive outcomes might be affected as a result of manganese exposure. According to the few available inhalation and oral studies in humans and animals, inorganic manganese exposure does not cause significant injury to the heart, stomach, blood, muscle, bone, liver, kidney, skin, or eyes. If, however, manganese is in the (VII) oxidation state (e.g., potassium permanganate), then ingestion may result in severe corrosion at the point of contact. There is no evidence for carcinogenicity of manganese in humans (ATSDR 2008).

MERCURY

Mercury is a naturally occurring element and exists in the environment in several forms: metallic or elemental mercury, inorganic mercury, and organic mercury. Mercury is naturally released into the environment as a by-product of erosion of rocks and soil, and from volcanic activity. Human industrial activities such as mining and burning of fossil fuels have resulted in additional environmental releases of mercury. Metallic mercury in its pure form is a shiny, silver-white liquid metal at room temperature, often used in thermometers and some electrical switches. Even at room temperature a certain amount of the metallic mercury will evaporate and form colorless, odorless vapors. Liquid metallic mercury releases more vapors at increasingly higher temperatures. Some people have reported a metallic taste in their mouths after breathing mercury vapors. Metallic mercury has been found at numerous hazardous waste sites across the United States. Inorganic mercury compounds (mercury salts) occur when the element combines with others such as chlorine, sulfur, or oxygen. Most of these mercury salts appear as white powders or crystals, except for mercuric sulfide (also known as cinnabar) which is red and turns black after exposure to light. When mercury combines with carbon it forms compounds called organomercurials, the most common of which is methylmercury (also known as monomethylmercury). In their pure form methylmercury and phenylmercury appear as white crystalline solids, whereas dimethylmercury is a colorless liquid. The most commonly occurring natural forms of mercury in the environment include metallic mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury. Methylmercury is produced primarily by microorganisms (bacteria and fungi) in the environment, rather than by human activity. Concern surrounding methylmercury is due to its tendency to bioaccumulate in various edible freshwater and saltwater fish and marine mammals (ATSDR 1999).

Toxicity

Most of the studies concerning inhalation exposure to mercury focus on metallic mercury vapor since other forms of inorganic mercury do not pose a risk by the inhalation pathway. Systemic toxicity in both humans and animals has been reported in association with inhalation of metallic mercury vapor, with the kidneys and the central nervous system as major target organs. Respiratory, cardiovascular, and gastrointestinal effects have also been reported in relation to high-exposure levels. Death from respiratory failure in humans has been reported following accidental acute exposure to high, but unspecified, metallic mercury vapor concentrations. Deaths in humans have also been reported in case studies of occupational exposure to alkyl mercury compounds; while the cause of death was not reported, most subjects died following development of profound neurotoxicity (ATSDR 1999).

SELENIUM

Selenium is an essential micronutrient for humans and animals that is found ubiquitously in the environment, being released from both natural and anthropogenic sources. The principal release of selenium into the environment from anthropogenic sources is from coal combustion. Natural sources of selenium include the weathering of selenium-containing rocks and soils, and volcanic eruptions. Selenium is found in most rocks and soils, and naturally occurs at low concentrations in surface waters and groundwaters of the United States. Accumulation of selenium in agricultural drainage waters has been documented in basins in the western United States, particularly in California. Ambient background concentrations of selenium in the air are very low, generally in the ng/m^3 range. Exposure of the general population to selenium is primarily by ingestion of its organic and inorganic forms, both of which occur naturally in the diet. Other exposure pathways for selenium, which are of lesser importance, are water and air. Various estimates of the selenium intake for Americans have ranged from 0.071 to 0.152 mg selenium/day (approximately 1 to 2 microagrams per kilogram per day [µg/kg/day] in adults). Some people living in areas with high soil concentrations of selenium (as in areas of the western United States) might have higher exposure because of the natural selenium levels found locally, particularly if they consume crops primarily grown in that area. Metal industry workers, health service professionals, mechanics, and painters may be exposed to higher levels of selenium than the general population or workers employed in other trades (ATSDR 2003).

Toxicity

Depending upon the level of intake, selenium can have both nutritional and potentially toxic effects. While excessive intake of selenium can result in adverse health effects, such toxicity is generally observed at doses over 5 times greater than the Recommended Dietary Allowance (RDA) established by the Food and Nutrition Board of the National Research Council (National Academy of Sciences). The current RDA for selenium is 55 µg/day for male and female adults (approximately 0.8 µg/kg/day). Chronic oral intake of selenium at 10 to 20 times higher than normal levels can produce selenosis in humans, with major health effects being dermal and neurological in nature. Intermediate and chronic oral exposure of livestock to high levels of dietary selenium compounds has been reported to produce dermal and neurological effects. Studies in rats and other laboratory animals with high selenium tissue concentrations demonstrate that many organ systems retain selenium and are affected. The primary adverse effects reported in laboratory animals exposed to inorganic selenium salts or to selenium-containing amino acids are cardiovascular, gastrointestinal, hematological, hepatic, dermal, immunological, neurological, and reproductive in nature. Doses required to cause these effects, however, are generally at least 5 times higher than normal daily selenium intake. Acute oral exposure to extremely high levels of selenium (e.g., several thousand times more than normal daily intake) produces nausea, vomiting, and diarrhea in both humans and laboratory animals and has occasionally caused cardiovascular symptoms, such as tachycardia. Acute- and intermediate-duration oral exposure to very large amounts of selenium (approximately 100 times normal human intake) has produced myocardial degeneration in laboratory animals (ATSDR 2003).

Cases of acute, high-level inhalation exposure of humans and laboratory animals to selenium dusts or fumes have resulted in toxicity to the lung, with cardiovascular, hepatic, nervous, and renal involvement as well. There are reports of acute occupational exposures to high concentrations of elemental selenium dust resulting stomach pain and headaches; also workers acutely exposed to elevated levels of selenium dioxide dust reported respiratory symptoms such as pulmonary edema, bronchial spasms, symptoms of asphyxiation and persistent bronchitis, elevated pulse rates, lowered blood pressure, vomiting, nausea, and irritability. No health effects data is available for humans or laboratory animals in relation to intermediate-duration (up to 1 year) inhalation exposure to selenium or selenium compounds. Several occupational studies are available regarding chronic inhalation exposure, reporting respiratory effects such as irritation of the nose, respiratory tract, and lungs, bronchial spasms, and coughing following exposure to selenium dioxide or elemental selenium as dust. Similar respiratory symptoms have also been reported in animal studies following inhalation exposures to high doses of elemental selenium fumes or dust (ATSDR 2003).

SILVER

Silver is a rare metal and one of the basic elements that make up the earth's crust. While silver occurs naturally in the environment as a soft, "silver" colored metal, it also occurs in compounds with either a powdery white (silver nitrate and silver chloride) or dark-gray to black (silver sulfide and silver oxide) color. Silver in its metallic form is commonly used to make jewelry, silverware, electronic equipment, and dental fillings. Silver compounds may be found at various environmental media at hazardous waste sites across the United States. Historically, photographers have used silver compounds to make photographs, with photographic materials being the major source of the silver that is released into the environment. Another source of environmental releases of silver is mining of silver and also other metals. Natural erosion and wearing down of silver-bearing rocks and soil by the wind and rain also releases large amounts of silver into the environment (ATSDR 1990).

Toxicity
Published human studies regarding inhalation of silver are predominantly based on exposure to elemental silver, silver nitrate, and silver oxide. Human data for oral exposures come from information on medicines containing silver, such as silver acetate-containing antismoking lozenges, breath mints coated with silver, and silver nitrate solutions for treating gum disease. Animal studies are usually based on exposure to silver nitrate and silver chloride in drinking water (ATSDR 1990).

Respiratory effects have been observed infrequently in humans following inhalation of silver compounds. Reported effects include respiratory irritation and abnormal lung function. Workers have also reported abdominal pain following exposure to silver nitrate and oxide in the workplace, with exposure levels estimated to be between 0.039 and 0.378 milligram per cubic meter ($mg/m^{3)}$ silver. Occupational exposure to silver metal dust has been associated with increased excretion of a particular renal enzyme, and with decreased creatinine clearance, both effects being diagnostic of marginally impaired renal function. Workers have also reported skin and ocular burns caused by contact with silver nitrate. Gray or blue-gray discoloration of the skin has been observed in individuals that have ingested both metallic silver and silver compounds in small doses over periods of months to years. Several reports describe the deposition of silver containing granules in central nervous system tissues. Several medical case histories indicate that extended dermal exposure to silver or silver compounds can lead to localized skin discoloration similar in nature to the pigmentation reported after repeated oral exposure. Decreased body weight gain was observed in guinea pigs following dermal application of 81 mg silver nitrate (2 milliliter [mL] of a 0.239 Molar [M] solution) to 3.1 square centimeter ($cm^{2)}$ of skin. Medical case histories describe mild allergic responses attributed to repeated dermal contact with silver and silver compounds (ATSDR 1990).

VANADIUM
Vanadium is the 22nd most abundant element in the earth's crust and is widely distributed. It occurs in nature as a white-to-gray metal, and is often found in the form of crystals. Vanadium usually combines with other elements such as oxygen, sodium,

sulfur, or chloride. It has oxidation states of +2, +3, +4, and +5. Because of its high melting point, it is referred to as a refractory metal. Most of the vanadium used in the United States is used to make steel.

Vanadium cannot be destroyed in the environment. It can only change its form or become attached to or separated from particles. Vanadium particles in the air settle to the ground or are washed out of the air by rain. Smaller particles, such as those emitted from oil-fueled power plants, may stay in the air for longer periods of time and are more likely to be transported farther away from the site of release. The transport and partitioning of vanadium in water and soil is influenced by many factors including acidity of the water or soil and the presence of particulates. Vanadium can either be dissolved in water as dissolved ions or may become adsorbed to particulate matter.

Toxicity

The DHHS and the EPA have not classified vanadium as to its human carcinogenicity. Exposure to vanadium may cause harmful health effects. The major effects from breathing high levels of vanadium are on the lungs, throat, and eyes. Breathing air with vanadium pentoxide can result in coughing which can last for a number of days after exposure. Vanadium is not readily absorbed by the body from the stomach, gut, or contact with the skin. However, nausea, mild diarrhea, and stomach cramps have been reported in people taking sodium metavanadate or vanadyl sulfate for experimental treatment of diabetes.

ZINC

Zinc is one of the most common elements in the Earth's crust. Zinc is found in the air, soil, and water and is present in all foods. In its pure elemental (or metallic) form, zinc is a bluish-white, shiny metal. Powdered zinc is explosive and may burst into flames if stored in damp places. Metallic zinc has many uses in industry. A common use for zinc is to coat steel and iron as well as other metals to prevent rust and corrosion; this process is called galvanization. Metallic zinc is also mixed with other metals to form alloys such as brass and bronze. A zinc and copper alloy is used to make pennies in the United States. Metallic zinc is also used to make dry cell batteries (ATSDR 2005).

Zinc enters the air, water, and soil as a result of both natural processes and human activities. Most zinc enters the environment as the result of mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes. These activities can increase zinc levels in the atmosphere. Waste streams from zinc and other metal manufacturing and zinc chemical industries, domestic waste water, and run-off from soil containing zinc can discharge zinc into waterways. The level of zinc in soil increases mainly from disposal of zinc wastes from metal manufacturing industries and coal ash from electric utilities. Sludge and fertilizer also contribute to increased levels of zinc in the soil. In air, zinc is present mostly as fine dust particles. Most of the zinc in lakes or rivers settles on the bottom. However, a small amount may remain either dissolved in water or as fine suspended particles. The level of dissolved zinc in water may increase as the acidity of water increases. Most of the zinc in soil is bound to the soil and does not dissolve in water. Zinc in aerobic waters is partitioned into sediments through sorption onto hydrous iron and manganese oxides, clay minerals, and organic material. Precipitation of soluble zinc compounds appears to be significant only under reducing conditions in highly polluted water. Generally, at lower pH values, zinc remains as the free ion. In anaerobic environments and in the presence of sulfide ions, precipitation of zinc sulfide limits the mobility of zinc. Zinc sorbs strongly onto soil particulates. Zinc in a soluble form (e.g., zinc sulfate) is moderately mobile in most soils. However, relatively little land-disposed zinc at waste sites is in the soluble form. Thus, mobility is limited by a slow rate of dissolution (ATSDR 2005).

Toxicity

Inhaling large amounts of zinc (as zinc dust or fumes from smelting or welding) can cause a specific short-term disease called metal fume fever, which is generally reversible once exposure to zinc ceases. However, very little is known about the long-term effects of breathing zinc dust or fumes. Eating food containing very large amounts of zinc (1,000 times higher than the RDA) for several months caused many health effects in rats, mice, and ferrets, including anemia and injury to the pancreas and kidney. Rats that ate very large amounts of zinc became infertile. Rats that ate very large amounts of zinc after becoming pregnant had smaller babies. Putting low levels of certain zinc compounds, such as zinc acetate and zinc chloride, on the skin of rabbits, guinea pigs, and mice caused skin irritation. Skin irritation from exposure to these chemicals would probably occur in humans. EPA has determined that because of lack of information, zinc is not classifiable as to its human carcinogenicity (ATSDR 2005).

PESTICIDES

Dichloro Diphenyl Ethylene (DDE) and Dichloro Diphenyl Trichloroethane (DDT)

DDT is a synthetic organochlorine pesticide. Technical grade DDT is a mixture of three isomers: p,p'-DDT (85 percent), o,p'-DDT (15 percent), and o,o'-DDT (trace amounts). DDT, DDE, and dichloro diphenyl dichloroethane (DDD) are white crystalline solids. DDT is a pesticide once widely used to control insects in agriculture and insects that carry diseases such as malaria. Its use in the U.S. was banned in 1972, but is still used in some countries. DDD was also used to kill pests, but its use has also been banned. Both DDE and DDD are degradation products of DDT (ATSDR 2002).

Before it was banned, DDT entered the air, water, and soil during its production and use as an insecticide. DDT still enters the environment because of its current use in other areas of the world. DDE is only found in the environment as a result of contamination or breakdown of DDT. DDT, DDE and DDD may also enter the air when they evaporate from contaminated water and soil. DDT, DDE, and DDD in the air will then be deposited on land or surface water. This cycle of evaporation and deposition may be repeated many times. As a result, DDT, DDE, and DDD can be carried long distances in the atmosphere. DDT, DDE, and DDD may occur in the atmosphere as a vapor or be attached to solids in air. Vapor phase DDT, DDE, and DDD may break down in the atmosphere due to reactions caused by the sun. Most DDT breaks down slowly into DDE and DDD in soil, generally by the action of microorganisms. They stick strongly to soil, and therefore generally remain in the surface layers of soil. Some soil particles with attached DDT, DDE, or DDD may get into rivers and lakes in runoff. Only a very small amount, if any, will seep into the ground and get into groundwater. The length of time that DDT will last in soil depends on many factors including temperature, type of soil, and whether the soil is wet. DDT disappears faster when the soil is flooded or wet than when it is dry. DDT disappears faster when it initially enters the soil. Later on, evaporation slows down and some DDT moves into spaces in the soil that are so small that microorganisms cannot reach the DDT to break it down efficiently. In temperate areas, half of the ΣDDT initially present usually disappears in about 5 years. However, in some cases, half of the ΣDDT initially present will remain for 20, 30, or more years. In surface water, DDT will bind to particles in the water, settle, and be deposited in the sediment. DDT is taken up by small organisms and fish in the water (ATSDR 2002).

Toxicity

The predominant route of exposure of the general population to DDT and its metabolites is through the diet. The main sources of DDT in food are meat, fish, poultry, and dairy products. The amount in food has greatly decreased since DDT was banned in the United States in 1972. Residues are more likely to occur in food imported from countries where DDT is still used (ATSDR 2002).

Acute-duration exposure to high concentrations of DDT can induce tremors and seizures which usually disappear after the exposure ceases. Several studies in humans suggest that high DDT/DDE burdens may be associated with alterations in end points controlled by hormonal action, such as duration of lactation, maintenance of pregnancy, and fertility. In animals, short-term exposure to large amounts of DDT in food affected the nervous system, while long-term exposure to smaller amounts affected the liver. Also in animals, short-term oral exposure to small amounts of DDT or its breakdown products may also have harmful effects on reproduction. Long-term exposure to DDT, DDE, or DDD has induced liver cancer in mice. The DHHS determined that DDT may reasonable be anticipated to be a human carcinogen. The International Agency for Research on Cancer (IARC) determined that DDT may possibly cause cancer in humans. The EPA determined that DDT, DDE, and DDD are probable human carcinogens (ATSDR 2002).

DIELDRIN

Aldrin and dieldrin are insecticides with similar chemical structures. They are discussed together because aldrin quickly breaks down to dieldrin in the body and in the environment. Neither substance occurs naturally in the environment and they are no longer produced or used. From the 1950s until 1970, aldrin and dieldrin were used extensively as insecticides on crops such as corn and cotton. The United States Department of Agriculture canceled all uses of aldrin and dieldrin in 1970. In 1972, however, EPA approved aldrin and dieldrin for killing termites. Use of aldrin and dieldrin to control termites continued until 1987. In 1987, the manufacturer voluntarily canceled the registration for use in controlling termites (ATSDR 2002).

The Henry's law constants of aldrin and dieldrin indicate that volatilization from moist soil surfaces will occur. Both compounds also bind strongly to soil particles and are often associated with dust particles in the atmosphere. Dieldrin in soil or water breaks down very slowly. Dieldrin sticks to soil and may stay there unchanged for many years. Water does not easily wash dieldrin off soil. Dieldrin does not dissolve in water very well and is therefore not found in water at high concentrations. Most dieldrin in the environment attaches to soil and to sediments at the bottoms of lakes, ponds, and streams. In the air, dieldrin changes to photodieldrin within a few days (ATSDR 2002).

Toxicity

Exposure of the general population to aldrin and dieldrin may occur through ingestion of contaminated food (including fish and shellfish) or water, through inhalation of contaminated air, especially in homes that have been treated with either pesticide, and through dermal contact with contaminated soil or water. The dietary contribution is likely the most significant route of human exposure. Dieldrin tends to be stored in high-fat tissues within the body, but can be mobilized during lactation or starvation (ATSDR 2002).

Aldrin and dieldrin are carcinogenic in animals, but this effect appears to be specific to the mouse liver. The IARC has categorized aldrin and dieldrin as Group 3 (unclassifiable as to human carcinogenic potential) chemicals. Based on the finding of liver tumors in mice, EPA classified both aldrin and dieldrin as B2, probable human carcinogens; however, current mechanistic data suggest that the mouse carcinogenicity data may not be highly relevant to humans. The preponderance of evidence appears to indicate that aldrin and dieldrin induce a carcinogenic response through nongenotoxic mechanisms. The major target organs that are affected from dieldrin exposure are the liver and central nervous system (ATSDR 2002).

ENDOSULFAN II (β-Endosulfan)

Technical-grade endosulfan contains at least 94 percent of two pure isomers, α- and β-endosulfan. The α- and β-isomers of endosulfan are present in the ratio of 7:3, respectively. Technical-grade endosulfan may also contain up to 2 percent endosulfan alcohol and 1 percent endosulfan ether. Endosulfan sulfate is a reaction product found in the environment due to photolysis and in organisms as a result of oxidation by biotransformation (ATSDR 2000).

Endosulfan enters air, water, and soil when it is manufactured or used as a pesticide. Endosulfan is often applied to crops using sprayers. Some endosulfan in the air may travel long distances before it lands on crops, soil, or water. Endosulfan on crops usually breaks down within a few weeks. Endosulfan released to soil attaches to soil particles. Endosulfan found near hazardous waste sites is usually found in soil. Some endosulfan in soil evaporates into air, and some endosulfan in soil breaks down. However, it may stay in soil for several years before it all breaks down. Rain water can wash endosulfan that is attached to soil particles into surface water. Endosulfan does not dissolve easily in water. Most endosulfan in surface water is attached to soil particles floating in the water or attached to soil at the bottom. The small amounts of endosulfan that dissolve in water break down over time. Depending on the conditions in the water, endosulfan may break down within 1 day or it may take several months. Because it does not dissolve easily in water, only very small amounts of endosulfan are found in groundwater (ATSDR 2000).

Toxicity

There is very little difference in toxicity between endosulfan and its metabolite, endosulfan sulfate. However, the α-isomer has been shown to be about three times as toxic as the β-isomer of endosulfan (ATSDR 2000). The DHHS, IARC, and EPA have not classified endosulfan as to its carcinogenicity. Results from animal studies show that exposure to very large amounts of endosulfan for short periods of time can cause adverse nervous system effects (such as hyper excitability, tremors, and convulsions) and death. Because the brain controls the activity of the lungs and heart, lethal or near lethal exposures in animals have also resulted in failure of these organs. Other effects seen in animals after short-term, high-level exposures include harmful effects on the stomach, blood, liver, and kidney. After somewhat longer exposures, the ability of animals to fight infection was also impaired. The kidney, testes, and possibly the liver, are the only organs in laboratory animals affected by longer-term exposure to low levels of endosulfan. The seriousness of these effects is increased when animals are exposed to higher concentrations of endosulfan (ATSDR 2000).

PENTACHLOROPHENOL

Pentachlorophenol is a synthetic substance, made from other chemicals, and does not occur naturally in the environment. Since 1984, the purchase and use of pentachlorophenol has been restricted to certified applicators. Before use restrictions, pentachlorophenol was widely used as a wood preservative. It is now used industrially as a wood preservative for power line poles, cross arms, fence posts, and the like (ATSDR 2001).

Pentachlorophenol released into the atmosphere from treated wood can be transported back to surface waters and soils via wet and dry deposition. Atmospheric pentachlorophenol is transformed via photolysis; the compound may slowly undergo free radical oxidation with an estimated half-life of approximately 2 months. In surface waters, pentachlorophenol undergoes biotransformation and photolysis, and is adsorbed to sediments. Hydrolysis, oxidation, and volatilization do not significantly affect surface water concentrations. In soils and sediments, pentachlorophenol is metabolized by acclimated microbes, under both aerobic and anaerobic conditions, or is adsorbed. Pentachlorophenol may also be methylated to form pentachloroanisole, a more lipid soluble compound. Adsorption of pentachlorophenol in soils is pH dependent. Adsorption decreases in neutral and basic soils and is strongest in acidic soils. Therefore, the compound is most mobile in neutral-to-basic mineral soils and least mobile in acidic organic soils. Volatilization and photolysis do not appear to be important transport and transformation processes for pentachlorophenol in soils. A

Henry's law constant of 2.75×10^{-6} atm m^3/mol has been reported for pentachlorophenol; the value for the salt or ionic form of this compound is expected to be much less. Therefore, volatilization of the solvated anionic form from an aqueous system is not considered to be a significant transport mechanism under ambient conditions. Photolysis and biodegradation are believed to be the dominant transformation processes for pentachlorophenol in aquatic systems. Pentachlorophenol is degraded under anaerobic conditions in sewage sludge and sediments (ATSDR 2001).

Toxicity

Short exposures to large amounts of pentachlorophenol in the workplace or through the misuse of products that contain it can cause harmful effects on the liver, kidneys, blood, lungs, nervous system, immune system, and gastrointestinal tract. Contact with pentachlorophenol (particularly in the form of a hot vapor) can irritate the skin, eyes, and mouth. If large enough amounts enter the body, heat is produced by the cells in the body, causing an increase in body temperature. The body temperature can increase to dangerous levels, causing injury to various organs and tissues and even death. An increased risk of cancer has been shown in some laboratory animals given large amounts of pentachlorophenol orally for a long time. There is weak evidence that pentachlorophenol causes cancer in humans. The IARC has determined that pentachlorophenol is possibly carcinogenic to humans, and the EPA has classified pentachlorophenol as a probable human carcinogen. The compound has been found to bioaccumulate to modest levels (e.g., bioconcentration factors of <1,000), but food chain biomagnification has not been observed (ATSDR 2001).

SEMI-VOLATILE ORGANIC COMPOUNDS (SVOC)

DIBENZOFURAN

Dibenzofuran is a white crystal-like solid that is created from the production of coal tar. Dibenzofuran is used as an insecticide and to make other chemicals. It is made from coal tar and has been found in coke dust, grate ash, fly ash, and flame soot. Dibenzofuran is released to the ambient air from combustion sources. It may be found in coke dust, grate ash, fly ash, and flame soot. The general public may be exposed to dibenzofuran through the inhalation of contaminated air or through the consumption of contaminated drinking water or food.

Dibenzofuran is a polynuclear aromatic compound with a molecular weight of 168.20 grams per mole (g/mol). Dibenzofuran occurs as white crystals or crystalline solid that has a solubility in water of about 3 mg/L at 25 °C. The odor threshold for dibenzofuran is about 1 milligram per cubic meter (mg/m^3). The vapor pressure for dibenzofuran is 0.0175 millimeter of mercury (mm Hg) at 25 °C, and its log octanol/water partition coefficient (log Kow) varies between 3.18 and 4.12. Dibenzofuran can enter your body when you breathe contaminated air. It can also be absorbed into your body when it comes into contact with your skin.

Toxicity

Little to no information is available on the health effects of dibenzofuran exposure. However, the information that does exist shows that short-term exposure to dibenzofuran can cause skin, eye, nose, and throat irritation. No information is available on the acute (short-term), chronic (long-term), reproductive, developmental, and carcinogenic effects of dibenzofuran in humans or animals. Health effects information is available on the polychlorinated dibenzofurans; however, the EPA has noted that the biological activity of various chlorinated dibenzofurans varies greatly, thus, risk assessment by analogy to any of these more widely studied compounds would not be recommended.

In a comparison of Toxic Equivalency Factor (TEF) values for chlorinated dibenzofurans, mono-, di- and tri-chlorinated dibenzofuran had TEF values of 0 (U.S. EPA, 1989). Based on these results and the fact that toxicity of polychlorinated dibenzofurans (PCDF) depends on the number of chlorine substituents and their position (U.S. EPA, 1986), the TEF for dibenzofuran, with no chlorine substituents, is set equal to 0.

The EPA has determined that there is not enough information available to classify dibenzofuran as a cancer causing substance.

VOLATILE ORGANIC COMPOUNDS

CARBON DISULFIDE

In nature, small amounts of carbon disulfide are found in gases released to the earth's surface, for example, in volcanic eruptions or over marshes. Microorganisms in the soil can also produce gas containing carbon disulfide. Commercial carbon disulfide is made by combining carbon and sulfur at very high temperatures. Several industries use carbon disulfide as a raw material to make such things as rayon, cellophane, and carbon tetrachloride. Currently, the largest user of this chemical is the viscose rayon industry. Carbon disulfide is also used to dissolve rubber to produce tires and as a raw material to make some pesticides (ATSDR 1996).

Carbon disulfide evaporates rapidly when released to the environment. The amount of carbon disulfide released into the air through natural processes is difficult to judge because it is in such small amounts in nature. This also makes it hard to monitor carbon disulfide and to explain how it behaves when it comes into contact with other compounds. Most carbon disulfide in the air and in surface water is from manufacturing and processing activities. However, it is found naturally in coastal and ocean waters.

Once released to the environment, carbon disulfide moves quickly to the air. Once in the air, it stays close to the ground because it is heavier than the surrounding air. It is estimated that carbon disulfide will break down into simpler components after approximately 12 days. Carbon disulfide moves through soils fairly quickly and normally evaporates rapidly. However, since carbon disulfide does not bind tightly to soils, the amount that does not evaporate can easily move down through the soil into groundwater. Since it is very mobile, it is not likely to stay in the soil long enough to be broken down. It does not remain very long in water either because it evaporates within minutes. However, if dissolved in water, it is relatively stable and is not easily broken down. It is estimated that carbon disulfide is not taken up in significant amounts by the organisms living in water (ATSDR 1996).

Toxicity

At very high levels (10,000 parts of carbon disulfide per million parts [ppm] of air), carbon disulfide may be life threatening because of its effects on the nervous system. Studies in animals indicate that carbon disulfide can affect the normal functions of the brain, liver, and heart. However, the amount of carbon disulfide in the air to which animals in these studies were exposed was much higher than the amounts in the air that the general public usually breathes. The brains, livers, and hearts of the animals were affected only after breathing air that contained carbon disulfide for days, months, or years. There is no information on health effects in people who eat food or drink water contaminated with carbon disulfide. No EPA, DHHS, or IARC cancer classifications were reported for carbon disulfide (ATSDR 1996).

ETHYLBENZENE

Ethylbenzene is a colorless liquid that smells like gasoline. It evaporates at room temperature and burns easily. Ethylbenzene is found naturally in oil. Large amounts of ethylbenzene are produced in the United States; most of it is used to make styrene. It is also used in fuels. Consumer products containing ethylbenzene include: gasoline, paints and inks, pesticides, carpet glues, varnishes and paints, tobacco products, automobile products. This compound is most commonly found in air. It moves easily into the air from water and soil. Ethylbenzene in soil can also contaminate groundwater. It is rapidly broken down in air, less than 3 days with the aid of sunlight. In surface water such as rivers and harbors, it breaks down by reacting with other compounds naturally present in water. In the soil, ethylbenzene is broken down by soil bacteria (ATSDR 2010).

Toxicity

Exposure to high levels of ethylbenzene in air for short periods can cause eye and throat irritation. Exposure to higher levels can result in dizziness. Irreversible damage to the inner ear and hearing has been observed in animals exposed to relatively low concentrations of ethylbenzene for several days to weeks. Exposure to relatively low concentrations of ethylbenzene in air for several months to years causes kidney damage in animals. The IARC has determined that ethylbenzene is a possible human carcinogen (ATSDR 2010).

3.2 DEVELOPMENT OF REMEDIATION GOALS

Preliminary remediation goals (PRGs) for the protection of upper trophic level (UTL) receptors of concern (ROCs) and benthic invertebrates were evaluated in the Sensitivity Analysis (Section 2.3). Various remediation scenarios involving sediment and soil PRGs were assessed for their predicted reduction in risk to UTL ROCs.

3.2.1 PRELIMINARY REMEDIATION GOALS FOR PROTECTION OF UPPER TROPHIC LEVEL RECEPTORS IN SEDIMENT

At the conclusion of the Sensitivity Analysis (Section 2.4), Remediation Scenario 10b was recommended by the EPA. This scenario involves a remediation of all sediment sample areas with an ERM-Q or PEL-Q Category Score greater than two to a PRG equal to one-half of the TCEQ-recommended first effects level benchmark for benthic invertebrates (TCEQ 2005). This sediment PRG resulted in acceptable Site-wide risk levels for UTL ROCs given the assumptions outlined in Section 2.4.7.

For several COPECs, the TCEQ did not provide a first effects sediment benchmark. In these cases, a value, such as a federal screening benchmark in sediment was used as a substitute. PRGs for UTL ROCs and their sources are documented in Table 3-4A.

3.2.2 PRELIMINARY REMEDIATION GOALS FOR PROTECTION OF BENTHIC INVERTEBRATES IN SEDIMENT

The final Remediation Scenario (10b) modeled risk to UTL ROCs based on remediation of sediment sample areas determined to be a risk to benthic invertebrates. Protection of benthic invertebrates was addressed with an EPA-recommended risk management strategy that involved addressing all sediment sample areas with an ERM-Q or PEL-Q Priority Category Score of three or four, corresponding to medium-high risk and high risk, respectively. Based on this evaluation method, benthic invertebrate PRGs were developed for those COPECs that are used in the ERM/PEL-Q Category Score calculation. For these COPECs, a TCEQ-recommended first effect benchmark was determined to be the most appropriate PRG for protection of benthic invertebrate because it can be viewed as the NOAEL concentration (TCEQ 2006).

While the ERM/PEL-Q method used in the Tier 2 RI was calculated using individual PAHs, a PRG for benthic invertebrates was developed for total PAHs. COPECs in this class of compounds demonstrate the same narcotic effect mechanism. Therefore, a PRG that evaluates impacts from all COPECs in the class is an appropriate value.

PRGs for benthic invertebrates and their sources are documented in Table 3-4A.

3.2.3 ECOLOGICAL PRELIMINARY REMEDIATION GOALS IN SEDIMENT

Sediment PRGs were developed for the protection of UTL ROCs and benthic invertebrates. The ecological PRG, which is protective of both of these receptor groups, is the lowest concentration of the UTL sediment PRG and the benthic invertebrate sediment PRG for each COPEC. According to 30 TAC §350.77, protective concentration levels for ecological receptors are primarily intended to be protective for more mobile or wide-ranging ecological receptors and, where appropriate, benthic invertebrate communities. Therefore, a PRG that protects UTL ROCs and benthic invertebrates in sediment is considered a protective concentration for ecological receptors in sediment and is equal to the ecological sediment PRG. Ecological sediment PRGs and their sources are documented in Table 3-4A.

3.2.4 PRELIMINARY REMEDIATION GOALS FOR PROTECTION OF UPPER TROPHIC LEVEL RECEPTORS IN SOIL

Remediation Scenario 10b was the final remediation scenario recommended by the EPA (see Sensitivity Analysis Section 2.4). This scenario involves a remediation of all soil sample areas (the Jefferson Canal Spoil Pile) to a PRG equal to the Texas-median background concentration provided by TCEQ (2005). This soil PRG resulted in acceptable Site-wide risk levels for UTL ROCs given the assumptions outlined in Section 2.4.7.

For several COPECs, the TCEQ did not provide a Texas-median background concentration. In these cases, a value, such as a soil ecological benchmark or federal background concentration, was used as a substitute. PRGs for UTL ROCs and their sources are documented in Table 3-4B.

3.2.5 ECOLOGICAL PRELIMINARY REMEDIATION GOALS IN SOIL

Soil PRGs were developed for the protection of UTL ROCs. According to 30 TAC §350.77, protective concentration levels for ecological receptors are primarily intended to be protective for more mobile or wide-ranging ecological receptors and, where appropriate, benthic invertebrate communities. Therefore, the UTL soil PRG is considered a protective concentration for ecological receptors and is equal to the ecological soil PRG. Ecological soil PRGs and their sources are documented in Table 3-5B.

3.2.6 HUMAN HEALTH PRELIMINARY REMEDIATION GOALS

The HHRA did not identify any potential risk from COPCs for human receptors that may utilize the Site. Therefore, no soil or sediment PRGs were needed or developed for the protection of human health.

3.3 GENERAL RESPONSE ACTIONS

General response actions were developed for sediment and soil that define containment, treatment, removal, or other actions, individually or in combination that may be completed to satisfy the RAOs for the Site. Areas of sediment impairment and corresponding volumes and soil impact were identified at which the general response actions may be applied. The areas or volumes to which the general response actions may be applied were based on the potential exposure routes, the nature and extent of impact, the preliminary remediation goals, and the preliminary list of action-specific ARARs. In addition, the requirements for protectiveness identified in the RAOs and the chemical and physical characteristics of the Site were considered during development of the general response actions.

The general response actions identified to meet the RAOs were selected from six primary remediation strategy categories. Table 3-5 identifies the general response actions that are relevant for consideration at the Star Lake Canal Superfund Site.

3.4 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

The potential remedial technologies and process options identified in the FS address the impacted sediment and soil at the Site and are summarized in this section. Various types of remedial technologies and process options were identified to achieve the goals of the general response actions. Remedial technologies are general categories of technologies and process options are the specific processes included within a remedial technology category.

3.4.1 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

A list of potentially acceptable technologies and technology process options, corresponding to the identified general response actions, were developed and screened by evaluation of the process options with respect to technical implementability. Each proposed potential technology was further evaluated during the FS for technical implementability, cost, and effectiveness in meeting the RAOs. This section describes methods and procedures used to identify and screen remedial technologies for the Star Lake Canal Superfund Site. The following procedure was used:

1. Identify general response actions that can achieve the remedial action objectives as defined in Section 3.1
2. Determine the method to initially screen the potential remedial technologies and establish the evaluation criteria

3. Based on the evaluation criteria, identify and screen the potential remedial technologies with respect to the characteristics of the impact and other Site-specific characteristics

The potential technologies were identified based on their estimated ability to reduce constituent concentrations in Site sediment and/or soil or to eliminate potential exposure pathways. Existing information on technologies and Site characterization data were used to screen process options that could not be effectively implemented at the Site. Table 3-6 includes a list of potential remedial technologies to address the identified sediment and soil impact at the Site including containment, removal, treatment, monitored natural recovery, and institutional controls. The physical and chemical methods for isolation or removal of impacted sediment and/or soil are described briefly in Table 3-6. Each potential technology was further evaluated during the FS for effectiveness, implementability, and cost in meeting the RAOs.

The ranking system used to screen the remedial technologies is described below and summarized in Table 3-7.

Effectiveness – Remedial technologies were rated for effectiveness using a numerical scale of 1 to 4. Remedial technologies that were determined not effective were given a ranking of 1. If the remedial technologies were slightly effective or the effectiveness could not be determined, the technologies were given a ranking of 2. Innovative technologies that have the potential to be effective based on results of previous applications were ranked with a 3. Remedial technologies that have a high probability of effectiveness and were effective in other applications were ranked with a 4.

Implementability – Remedial technologies were rated on a scale of 1 to 4 regarding implementability. Technologies that cause a high degree of disruption in the project area and require a significant amount of specialized equipment, technical knowledge, and/or permits were ranked with a 1. A ranking of 2 indicates that the technology may cause a medium amount of disruption in the project area and require a moderate amount of specialized equipment, technical knowledge, and/or permits. Technologies causing a minimal amount of disruption in the project area and do not require specialized equipment, technical knowledge, and or permits were ranked with a 3. If no disruption of the project area and a minimal amount of equipment is required, the technology was ranked with a 4.

Cost – The costs of remedial technologies were rated on a scale of 1 to 4. The most costly remedial technologies were ranked with a 1. Remedial technologies that have moderate costs were ranked with a 2. Low cost remedial technologies were ranked with a 3. Rankings of 4 were given to those technologies that have no costs associated with them.

Potential remedial technologies screened included No Action, containment, removal, treatment, monitored natural recovery, and institutional controls. Table 3-8 includes the screening results of the potential remedial technologies. Specific remedial technologies were retained based on the screening results.

3.4.2 EVALUATION OF TECHNOLOGIES AND SELECTION OF REPRESENTATIVE TECHNOLOGIES

The selection of representative process options is intended to simplify the development and evaluation of alternatives. The specific process options will be selected in order to develop and evaluate remedial alternatives and will represent the broader range of process options with each general technology type. Additional or alternative process options may be selected during the remedial design, if they are found to be more advantageous. The initial screening evaluated each technology type for effectiveness, implementability, and cost. Remedial technologies and process options that do not have the capability to effectively isolate, reduce, or eliminate soil/sediment impact were eliminated. Remedial technologies and process options that were retained and carried forward to develop remedial alternatives are presented in Table 3-9. These remedial technologies and process options shall be implemented individually or in combination, and are discussed in detail in Section 5.0 of this submittal.

As noted in Table 3-8, various process options within a remedial technology type may achieve the remedial action objectives as defined in Section 3.1. When possible, one representative process option was selected for use in establishing remedial alternatives and cost estimates. Additional or alternative process options may be identified and used during the remedial design if such process options are determined to be more successful with respect to achieving the RAO while meeting the aforementioned criteria.

The remedial technologies retained after screening include No Action, MNR, in-situ capping, dredging or excavation, and off-Site disposal. The following provides a summary of the technologies retained after screening.

No Action - No Action does not reduce the risk to benthic invertebrates and the environment but is retained to serve as a baseline for comparing the effectiveness of the remedial alternatives applicable to the Site.

MNR - The remedial technology types included in the evaluation of MNR are chemical/physical transport and degradation, biological degradation, and the physical burial process. The long-term effectiveness is heavily related to Site specific conditions. Chemical/Physical Transport may dilute and remove affected sediments from an implementation area, while having the negative effect of dispersal of COCs to a larger area downstream. Degradation may result in breakdown of PCBs, pesticide, PAHs, SVOCs, and VOCs while leaving metals in place. All MNR process options have low short-term effectiveness because of dependence upon the optimization of natural processes over time. Implementability of all process options are high because minimal action is taken, and all implementation can be performed using commercially available materials, equipment, and personnel. MNR is conditionally feasible, when multiple processes may be used to effectively reduce risk.

Containment – An in-situ cap is highly effective since COCs are isolated from the environment by the cap. Typical estimated breakthrough of organic COCs for most composite caps, reactive caps, armored caps, or containment pipes is on the order of hundreds of years. Impacted sediments may be temporarily re-suspended during the installation of the cap thus reducing the short-term effectiveness. The implementability of an in-situ cap will cause a medium degree of disruption in the project area and a moderate amount of specialized equipment, technical knowledge, and permits will be required. Maintenance dredging may affect the stability of the cap. An evaluation of the final cap elevation and the depth of maintenance dredging is critical to minimize the possibility of structural degradation resulting from maintenance dredging. An in-situ cap is considered feasible for the remediation of the COCs.

Removal/Disposal – Removal by dredging or excavation has high long-term effectiveness for permanent elimination of the pathway between COC-affected sediment or soil and the environment. During dredging or underwater excavation, impacted sediments may be temporarily re-suspended in the water column thus reducing the short-term effectiveness of dredging or excavation. Regarding implementability, dredging or excavation will cause a medium degree of disruption in the area. A moderate amount of equipment, technical knowledge, and permits will be required. Dredging or excavation is considered feasible for the remediation of the Site. Removed sediment or soil will be transported for disposal at an approved waste treatment facility.

4.0 EVALUATION OF GENERAL RESPONSE ACTIONS AND DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

This section describes methods and procedures used to assemble the selected general response actions and prepare remedial action alternatives. These alternatives represent a range of treatment activities and combinations of several technologies. General response actions assembled as alternatives for the screening process only include those options that have a significant potential for implementation at the Site. General response actions are described as classifications of remedial techniques (monitored natural recovery, containment, removal and disposal, etc.), while technology process options are individual remedial techniques (armor cap, composite cap, hydraulic dredge, etc.) considered for implementation at the Site. The application of the technology process options to each AOI is addressed further in Section 5.0.

The following sections screen the four retained general response actions from Section 3.4.2 of No Action, MNR, containment, and removal/disposal for effectiveness, implementability, and cost.

4.1 GENERAL REPONSE ACTION SCREENING CRITERIA

General response actions are screened to evaluate use for remediation of COC-affected media, addressing Site settings as applicable. Examples of Site settings include areas beside or under water, limited access, limited staging areas, and large treatment volumes. Additionally some of the areas are under additional guidelines such as Section 10 of the Rivers and Harbors Act of 1899 for navigable waters of the United States. The basic criteria for evaluation of each technology process option in this section are effectiveness, implementability, and cost.

Effectiveness

Effectiveness addresses the ability of the remedial technology to meet the RAOs given the present conditions and limitations of the AOI. Effectiveness is evaluated based on the reduction of toxicity, mobility, or volume of COC-affected sediments or soils. Short-term effectiveness considers how promptly risk is reduced; whereas long-term effectiveness considers the permanent nature of the technology and the ability to sustain the reduction of risk and exposure to COCs detected at the AOI. Remedial technologies with potentially low levels of effectiveness have been eliminated through this evaluation process.

Implementability

Implementability is evaluated based on Site-specific technical and administrative feasibility factors associated with the application of the remedial technology considered.

Technical feasibility addresses the ease of construction and availability of necessary resources for implementation of the technology. Long-term maintenance and monitoring requirements following the implementation of the remedial action are also considered.

Administrative feasibility addresses the capability to fulfill legal and regulatory requirements, and submit necessary permits in order to apply a given remedial technology. Administrative feasibility also incorporates the ability to overcome physical obstructions, proximity of treatment and disposal facilities, and the coordination of Site operations.

Remedial technologies with potentially low levels of implementability for a given AOI are eliminated through this evaluation process.

Cost

Cost is considered based on general cost estimates for implementation of each remedial technology, and evaluated as low, moderate, or high. The cost for each technology is estimated in more detail in Section 6.0.

4.2 EVALUATION OF GENERAL RESPONSE ACTIONS

Alternatives are screened to evaluate use within the two media, sediment and soil. Each general response action is also screened for appropriate use with the Site-specific settings under consideration. Examples of Site settings include areas beside or under water, limited access, limited staging areas, and large treatment volumes. Additionally, some of the areas are under additional guidelines such as Section 10 for navigable waters of the United States.

The following sections provide brief descriptions of the retained general response actions from Section 3.4.2 and an assessment of the general response actions based on the screening criteria described in Section 4.1.

4.2.1 GENERAL RESPONSE ACTION 1 – NO ACTION

Consideration of a No Action response is required by the EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA, 1988). The No Action response has been included to provide a basis for the comparison of the remaining general response actions. Under this response, No Action would be taken to isolate, remove, treat, or contain COCs in the sediment or soil at the Site. COC-affected media would remain in place and the potential for continued migration of constituents would not be mitigated. Additionally, no controls would be implemented to prevent intrusive activities, such as benthic invertebrate burrowing into the affected sediment.

Assessment

The No Action response does not reduce the toxicity, volume, or mobility of the constituent affected media. Since it does not result in any significant change in the risks associated with the COC-affected sediment or soil, the effectiveness on a long- and short- term basis is considered very low. The No Action response is minimally disruptive, has a low cost, and is highly implementable as no actions are taken, but due to its lack of risk reduction, it is considered not feasible or acceptable for the remediation of COCs within any of the areas to be addressed in the AOIs for this FS.

4.2.2 GENERAL RESPONSE ACTION 2 – MONITORED NATURAL RECOVERY (MNR)

MNR is a response for COC-affected sediment that uses natural processes (i.e., degradation, transport of sediments) to contain, destroy, or reduce toxicity or the bioavailability of constituents. Multiple natural occurring processes may be optimized to isolate, degrade, and remove COCs from the benthic environment. MNR is a gradual process, with a recovery time of years to decades. MNR types include chemical/physical processes, biological processes, and physical processes.

The chemical/physical transport process option optimizes the natural activities of sorption, desorption, dispersion, diffusion, dilution, volatilization, re-suspension, and transport. The timeframe for this process option varies with each activity, COC, and Site condition.

The biological degradation process option optimizes the natural attenuation of COCs by native aerobic or anaerobic bacteria. PCBs and pesticides may be dechlorinated, and PAHs, SVOCs, and VOCs may be partially or completely degraded.

The physical burial process option optimizes natural sedimentation and deposition to bury the affected materials in place. Additional deposition of clean sediment into the environment may lead to natural placement of an isolation layer between COC-affected sediments and the water column.

Assessment

The MNR response has low to high long-term effectiveness depending on the process option selected and the Site conditions. Chemical/physical transport may dilute and remove affected sediments from an implementation area, while having the negative effect of dispersal of COCs to a larger area downstream. Degradation may result in the breakdown of PCBs, pesticides, PAHs, SVOCs, and VOCs while leaving metals in place. All MNR process options have low short-term effectiveness because of the dependence upon the optimization of natural processes over time.

Implementability of all process options is high because minimal action is taken, and all implementation can be performed using commercially available materials, equipment, and personnel. MNR is conditionally feasible, when multiple processes are used to effectively reduce risk.

Cost of all process options within MNR is moderate, and depends on long-term sampling requirements.

Within the Star Lake Canal Superfund Site, the conditions present within the Molasses Bayou may allow for optimization of multiple natural recovery processes. Low velocity water movement minimizes erosion and bioturbation, while allowing some physical and biological processes to occur within the sediment.

4.2.3 GENERAL RESPONSE ACTION 3 – CONTAINMENT

Containment includes a range of options by which the pathway between constituents and the environment is interrupted by a physical barrier. This barrier eliminates direct contact between benthic invertebrates and constituent affected sediment, and also discourages constituent migration. Examples of containment techniques potentially appropriate for the Site include: sand caps, clay caps, composite caps, reactive caps, and pipe systems.

The sand or clay cap process options are implemented by covering affected sediment or soil with clean material to isolate COCs from the surrounding environment. When saturated, the caps form a continuous, impermeable barrier between constituent affected sediments and the water column. This option provides long-term protection of benthic invertebrates and the environment, and produces a new benthic habitat. In high water velocity settings, clay caps are more resistant to erosion, though either cap option can be reinforced by an armor cap. Sand or clay caps can also be used for containment of soils in non-aquatic environments, but in non-saturated settings clay caps are more suitable for isolation of constituents.

The armored cap process option reduces erosion and bioturbation that may not be provided by other cap types. An armored cap consists of a layer of cobbles, pebbles, or another large material and prohibits disturbance by its ability to burrow organisms, stabilize materials, and prevent erosion.

The composite cap process option consists of soil, stabilizing media, and geotextile (synthetic fabric for additional stabilization) placed over sediments or soils to inhibit migration of impaired pore water and to discourage bioturbators such as burrowing invertebrates. Composite cap mixtures include the use of a variety of materials to form the stabilizing aggregate; bentonite clay, other clay particles, or polymers are used frequently. When compared to sand caps, composite caps may reduce the necessary cap thickness by more than 90 percent.

The reactive cap process option uses amendment materials such as activated carbon or apatite that inhibit mobilization of COCs via chemical binding. Reactive materials may be imbedded in a geotextile, or a granulated stabilizing mixture. Implementation is similar to that of a composite cap, but the chemical binding may reduce the necessary thickness of the cap.

The pipe and cover process option encloses the channel flow within a pipe designed to meet necessary hydraulic capacity. The sediments no longer have contact with the flowing water and may be removed or capped in place with a layer of sand or clay.

Assessment
The containment response action has high effectiveness because COCs are isolated from the environment on a long-term basis. Typical estimated breakthrough of organic COCs for most clay caps, composite caps, reactive caps, or containment pipes, is on the order of hundreds of years. The isolation provided by the containment response action is also effective on a short-term basis, though during implementation COC-affected sediments may be temporarily re-suspended in the water column.

Implementability of the containment response action is moderate to high depending on Site conditions because all of the containment technologies described above can be implemented using commercially available materials, equipment, and personnel. Administrative responsibilities would include rental of appropriate equipment, and coordination with multiple vendors for containment material delivery. Reactive caps require specific knowledge of constituents, and appropriate selection of amendment mixtures to verify reaction of all constituents. For example, the CETCO Reactive Core Mat, may be designed to include organoclay and apatite; organoclay to react with PAHs, PCBs and other organics; and apatite to react with heavy metals.

The cost of the containment response action is moderate to high, depending upon Site conditions and includes materials, transportation, and monitoring. In general, materials for a clay cap have the lowest cost and are locally available; materials for a composite cap or reactive composite cap will include some clay and other materials which may be produced and transported by specific non-local suppliers.

A containment response could be engineered to meet the Site conditions of any of the six AOIs. Combinations of process options may be necessary to adjust for the degree of necessary resistance against erosion, COC migration, and penetrability by invertebrates. In the Jefferson Canal AOI, where certain portions require a very specific hydraulic capacity, a pipe could maintain that requirement. The Jefferson Canal Spoil Pile AOI, where the soil is not saturated, a clay or composite could will be used to prevent rainwater penetration. In Star Lake Canal AOI, where the water velocity may cause erosion, an armor cap will act as a protective layer over a clay, composite, or reactive cap. In Star Lake Canal AOI, Gulf States Utility Canal AOI, Molasses Bayou Waterway AOI, and Molasses Bayou Wetland AOI, where the water velocity is low, clay, composite or reactive caps will remain stable.

4.2.4 GENERAL RESPONSE ACTION 4 – REMOVAL AND DISPOSAL

The removal and disposal alternative involves extraction of the affected sediments or soils by excavation or dredge, followed by permanent disposal of those materials at an appropriate off-Site facility.

The excavation process option involves the removal of affected sediments using standard heavy equipment, excavation attachments on a marsh buggy, or similar amphibious heavy equipment. Following excavation, constituent affected sediments can be disposed at an approved off-Site landfill.

The hydraulic dredge process option is an appropriate removal alternative for sites involving underwater sediments with low accessibility. During hydraulic dredging a pump provides suction to move the sediment slurry through a pipeline to a land-based dewatering area. The dredged material can be disposed at an approved off-Site landfill, or contained on-Site.

Assessment

The removal and disposal general response action has high long-term effectiveness because by removal of the COC-affected material, pathways for exposure are permanently eliminated. Short-term effectiveness of this alternative corresponds to the time required for implementation. Though during dredging or underwater excavation COC-affected sediments may be temporarily re-suspended in the water column, sediment dispersion can be mitigated by the use of curtains or other suspended barriers within the waterway.

Implementability of the removal and disposal response is moderate to high depending on Site conditions because excavation or dredging can be performed using commercially available materials, equipment, and personnel; however, removal causes disruption and suspension of sediments in the water column. Administrative responsibilities would include rental of appropriate equipment, submittal of waste profiles, and coordination of transportation with disposal facilities.

The cost of the removal and disposal response is moderate to high depending on Site conditions, quantities, accessibility, and transportation. The costs include heavy equipment (for excavation or dredge), waste transportation and disposal, waste permits, and cost of backfill materials and transportation if applicable.

A removal and disposal response could be engineered to meet the Site conditions of any of the seven AOIs. The process option selection depends upon the accessibility of each AOI. Jefferson Canal AOI and Jefferson Canal Spoil Pile AOI are directly accessible by road and the material from both AOIs could be excavated directly into transportation trucks. Portions of other AOIs are accessible by either excavator or marsh buggy, however, due to its marsh surroundings some portions in Molasses Bayou AOI may necessitate the use of a hydraulic excavator.

4.3 DEVELOPMENT OF ALTERNATIVES

Potential interaction between each alternative and media has been considered during development and selection of alternatives. In addition, consideration has been given to suitability of the general response for the Site setting. The range of alternatives developed for sediment and soil includes combinations of No Action, MNR, containment, and removal and disposal. The alternative development process focused on the most viable options for remediation of the Site sediment and soil, as appropriate. Alternatives formed for each AOI are as follows:

Jefferson Canal AOI
Alternative 1: No Action
Alternative 2: Containment and 12-inch Removal/Disposal and Backfill: Pipe Containment
Alternative 3: 12-inch Removal/Disposal and Backfill

Jefferson Canal Spoil Pile AOI
Alternative 1: No Action
Alternative 2a: Containment – without Excavation: Composite Cap
Alternative 2b: Partial Containment – without Excavation: Composite Cap
Alternative 3a: Partial 12-inch Removal/Disposal and Containment: Composite Cap
Alternative 3b: Partial 12-inch Removal/Disposal and Partial Containment: Composite Cap

Former Star Lake AOI
Alternative 1: No Action
Alternative 2: 12-inch Removal/Disposal and Containment: Impermeable Cap
Alternative 3: 12-inch Removal/Disposal and Containment: Soil Cap

Star Lake Canal AOI
Alternative 1: No Action
Alternative 2: 12-inch Removal/Disposal and Containment: Impermeable Cap
Alternative 3: 12-inch Removal/Disposal and Containment: Armored Cap

Gulf States Utility Canal AOI
Alternative 1: No Action
Alternative 2: Containment – without Excavation: Composite Cap
Alternative 3: 12-inch Removal/Disposal and Containment: Armored (protective) Cap
Alternative 4: 12-inch Removal/Disposal

Molasses Bayou AOI – Waterway Polygons
Alternative 1: No Action
Alternative 2: Monitored Natural Recovery
Alternative 3: 12-inch Removal/Disposal and Containment: Armored (protective) Cap

Molasses Bayou AOI – Wetland Polygons
Alternative 1: No Action
Alternative 2: Monitored Natural Recovery
Alternative 3: Containment – without Excavation: Composite Cap
Alternative 4: 12-inch Removal/Disposal and Containment: Armored (protective) Cap
Alternative 5: 12-inch Removal/Disposal

5.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This section describes the process that will be used to further refine the remedial action alternatives and conduct a detailed analysis of the alternatives with respect to the evaluation criteria. The objective of the detailed analysis is to provide EPA with adequate information to select an appropriate remedy for the Site. The results of the detailed analysis of remedial action alternatives provide the basis for identification of a preferred alternative and preparation of a proposed plan.

5.1 REGULATORY REQUIREMENTS

The detailed analysis should address the statutory requirements for each remedial action. Remedial actions are required to:

- Be protective of human health and the environment
- Attain ARARs or provide justification for a waiver
- Be cost-effective
- Utilize permanent solutions and alternative treatment technologies, or resource recovery technologies, to the maximum extent practical
- Satisfy the preference that reduces toxicity, mobility, or volume of the constituents as a principal element or provide an explanation as to why it does not

In addition, CERCLA requires consideration of long-term effectiveness of each of the alternative remedial actions including:

- The long-term uncertainty associated with land disposal
- The goals, objectives, and requirements of the Solid Waste Disposal Act
- The persistence, toxicity, and mobility of hazardous substances and their constituents, and their propensity to bioaccumulate
- Short- and long-term potential for adverse health effects from human exposure
- Long-term maintenance costs
- The potential for future remedial action costs if the alternative remedial action implemented were to fail
- The potential threat to human health and the environment associated with excavation, transportation, and redisposal or containment

5.2 EVALUATION CRITERIA

The nine criteria used in the FS process during the evaluation of remedial alternatives provide the framework for conducting a detailed analysis for selection of appropriate remedial actions. The individual analysis of alternatives includes an evaluation of the performance of each alternative with the evaluation criteria, highlighting the performance of each alternative relative to specified criteria. The threshold criteria relate directly to statutory findings that must ultimately be met and, therefore, each remedial alternative must meet the overall protection of human health and the environment and compliance with the ARARs at the Site. The balancing criteria represent the primary criteria upon which the technical analysis of remedial alternatives are based. These criteria are characterized by the role of the criteria during the remedy selection process. There are threshold, balancing, and modifying criteria to be considered in this evaluation process.

The threshold criteria are:

- Overall protection of human health and the environment
- Compliance with the ARARs

The balancing criteria are:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

The modifying criteria are:

- State acceptance
- Community acceptance

These are further explained in the following paragraphs.

Overall Protection of the Environment

This is the first of two threshold factors used to screen alternatives. Threshold factors must be met for an alternative to be eligible for selection. Evaluation of the overall protectiveness of an alternative focuses on how well the alternative will achieve protection over time and how well it will reduce risk. This evaluation is intended to determine how well the risk posed by each pathway associated with each media is eliminated, reduced, or controlled through treatment and engineered controls. For the Site, protection is accomplished through interruption of the exposure pathway between COC-affected sediments and benthic invertebrates.

Compliance with ARARs

This is the second of the two threshold factors used to screen alternatives. The alternatives must conform to the effects of federal, state, and local requirements, regulations, and other institutional considerations relative to the design, operation, and timing of each option evaluated. The ARARs for the Site are identified and described in Section 3.1.1 and Tables 3-1 through 3-3.

Long-term effectiveness and permanence

This is the first of the primary balancing factors used to assess the qualitative reduction of risk to the environment. The evaluation of long-term effectiveness addresses the ability of a given alternative to maintain or continue reduction of risk for an extended period of time following implementation.

Reduction of toxicity, mobility, or volume

Reduction of toxicity, mobility, or volume is a primary balancing factor that addresses the method by which risk is reduced. For example, alternatives causing reaction or sorption of constituents reduce the toxicity of constituent affected sediments or soils, while barriers reduce mobility, and removal methods reduce volume present.

Short-term effectiveness

This primary balancing factor addresses the immediacy with which an alternative has affect on risk reduction. Alternatives that reduce risk upon implementation are considered to have high, short-term effectiveness; alternatives that reduce risk gradually are considered to have low, short-term effectiveness.

Implementability

Implementability is a primary balancing factor used to evaluate the characteristics that would prevent or enable the commencement of an alternative. Technical operations, disruption of the project area, administrative requirements, and long-term maintenance and testing requirements are all taken into account.

Cost

Cost is a primary balancing criterion addressed based on specific estimates for each technology process option and AOI. This evaluation is discussed in detail in Section 6.0.

State and Community acceptance

The final two criteria, state acceptance and community acceptance, are considered modifying considerations. These will be addressed once the ROD is released and presented for public comment. This evaluation will address any technical and administrative issues or concerns that the state and/or community may have with a proposed remedial alternative. Based on the comments received from the state and community, the EPA may modify components of the preferred alternative or decide that another alternative is more appropriate.

These threshold and balancing criteria were used to evaluate each remedial alternative for each AOI and are presented in the following sections.

5.3 INDIVIDUAL ANALYSIS OF ALTERNATIVES

As part of the screening process, general response actions have been analyzed to address the removal of the COCs for reduction of risk to the benthic organisms and the environment. Using these refined response actions, more detailed information pertinent to each of the technology process options is documented.

Remedial action alternatives retained through the screening process include those options that have a significant potential for implementation at the Site. An evaluation of the developed remedial action alternatives is conducted in this section based not only on screening for effectiveness and implementability, but taking into account the nine screening criteria and AOI specific conditions. Technology process options with insufficient degree of effectiveness or implementability have been eliminated from subsequent consideration within the FS.

For the Site, COCs include PCBs, PAHs, and metals; few remedial alternatives have capabilities to treat this range of constituents. The following remedial alternatives have been eliminated in prior stages of the FS because they do not isolate, remove or treat the organic COCs: physical burial process MNR, in situ chemical treatment, in situ physical treatment, ex situ chemical treatment, and ex situ chemical/physical treatment. The following remedial alternatives have been eliminated because they do not isolate, remove, or treat the metal COCs: biological degradation MNR, in situ biological degradation, and ex situ biological treatment.

The remaining remedial alternatives are considered potential options, and are evaluated for each AOI in this section. The following analysis refines applicable alternatives with respect to the physical setting and accessibility of each area of investigation.

5.3.1 JEFFERSON CANAL

Access to this section of the canal is limited to the public by a secure 8-foot-tall chain link fence within the Huntsman Chemical Plant. The canal is trapezoidal with a variable bottom width between 4-10 feet, 2:1 side slopes, and is partially lined with concrete. The canal passes beneath Hogaboom Road and transitions to a grass-lined canal with a less defined shape. Jefferson Canal extends another 2,200 lf to a box culvert that goes beneath Farm to Market Road 366 (FM 366). The side slopes for this grassed section are about 12:1 and the bottom width is about 10-20 feet. Jefferson Canal at this location is vegetated with trees on both sides. Several locations have wider cross sections and have side slopes of about 4:1. This canal is often partially inundated with water from storm runoff and a high water table. Water depth varies from 2.0-4.0 feet and is primarily influenced by surface runoff; tidally influenced in lower reaches. The bottom is soft with 8-10 inches of fine sediment easily resuspended. For the scope of the FS, Jefferson Canal is assumed to be a wetland.

All pipelines at or near the Jefferson Canal AOI will be taken into consideration for all remedial alternatives developed for this AOI. Refer to Appendix A to view the pipelines in the vicinity of Jefferson Canal AOI. Thiessen polygons for Jefferson Canal AOI are shown on Figure 5-1. Individual analysis of remedial alternatives for Jefferson Canal AOI are summarized in Table 5-1.

5.3.1.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between benthic invertebrates and the sediment, nor does it reduce the volume or mobility of the COC-affected sediments identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility or volume of COCs, nor does it prevent or reduce risk of exposure to receptors.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs**.**

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.1.2 ALTERNATIVE 2 – CONTAINMENT AND REMOVAL/DISPOSAL AND BACKFILL: PIPE CONTAINMENT

Jefferson Canal functions as a storm water conveyance canal with a required hydraulic capacity. Pipe containment is feasible along specific portions of Jefferson Canal identified by the Thiessen Polygon methodology presented in the Alignment Document. This alternative is viable for the polygons associated with sample JC-7 of the canal between the Huntsman Plant and the box culvert at FM 366. The pipe would be designed to maintain the required hydraulic capacity along the piped section of the reach. The section would be prepared by the removal of some of the affected sediment, then the pipe would be bedded on limestone or sand wrapped in geotextile fabric. The pipe may be partially buried to maintain the natural bottom of the canal. The section between the pipe and existing side slopes would be backfilled with clean fill up to the elevation of the adjacent embankment. The backfill would be compacted to stabilize both the pipe and embankment. This alternative would further isolate the affected sediments from the environment, and prevent constituent migration. A hydraulic analysis would be conducted in order to size the pipe to safely convey the design storm event.

For the remainder of the polygons associated with samples JC-2, JC-13, JC-18, and JC-19, the affected COCs would be excavated to a depth of 12 inches. All removed sediment would be dewatered, if needed, and properly disposed off-Site. These excavated areas shall be backfilled with clean fill and stabilized along the bottom and sides of the canal. Additionally, sediment and erosion control best management practices such as silt curtains will be installed in the canal to prevent the migration of COC-affected sediments resuspended during the excavation process.

The soil classification for this section of the Jefferson Canal is identified as partially hydric. Wetland disturbance requires additional permitting and any altering of the wetland requires mitigation in the form of fees and additional wetland creation.

Overall Protection of the Environment

This alternative serves to protect the environment by permanently disrupting the pathway between COCs and benthic organisms. The COCs are either to be isolated and immobilized, or removed completely depending on which solution is utilized in this alternative. Excavation will require the sediment to be dewatered (possibly treated) and disposed. Clean sediment will be brought in to replace the sediment removed in order to maintain the hydraulic capacity of the canal; embankment will be restabilized with seed impregnated sediment and erosion control matting.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of this action is high because this alternative provides a permanent long-term solution to exposure of COCs within the sediment.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments, however, through excavation of the Jefferson Canal AOI, mobility is eliminated and volume is reduced. The pipe further isolates any remaining sediment, eliminating mobility of the COCs to the benthic environment.

Short-term effectiveness

Implementation of the pipe containment alternative provides a highly effective barrier between benthic invertebrates and the COCs. Short-term effectiveness depends upon the duration of implementation, the time it takes to sandbag and dewater the area, excavate approximately one foot of sediment, lay geotextile or a thin layer of sand, set precast concrete pipe, backfill to grade, and vegetatively stabilize the canal. This alternative provides immediate relief from exposure to affected sediment upon implementation. Implementation of the excavation and removal portion of the alternative provides a highly effective short-term solution to contact between benthic invertebrates and the COCs. Once the sediment is removed and fresh fill is introduced for stabilization of the canal, the risk to benthic invertebrates from exposure to COC-affected sediment is eliminated. Additionally, care will be taken to install best management practices such as silt curtains to trap any affected sediment that may become resuspended in the water column by the excavation process.

Implementability

The pipe containment alternative has a high degree of implementability, because, materials and equipment are readily available. During implementation, logistical considerations will include proper timing of water diversion during preparation and pipe placement, staging requirements for backfill and equipment and development of an erosion control plan to keep COC-affected sediment out of the waterway. A hydraulic analysis will be conducted during the design to verify that the capacity of the pipe is adequate for current flow and will safely convey the design event. Additionally, the removed COC-affected sediment must be dewatered and disposed at an authorized facility. The excavation and removal/disposal portion of the alternative is also highly implementable and will not require any diversion of the stream; however, it will require the removed sediment to be dewatered and transported to an appropriate disposal facility. Materials and equipment are also readily available for removal/disposal.

5.3.1.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND BACKFILL

The 12-inch removal/disposal and backfill alternative will be applied to polygons corresponding to sample numbers JC-2, JC-7, JC-13, JC-18 and JC-19.

Overall protection of the environment

The 12-inch removal/disposal alternative serves to protect the environment through permanent elimination of the pathway between COCs and benthic organisms. The COC-affected sediments would be removed from the AOI.

Compliance with the ARARs

This alternative will be designed to comply with chemical-specific, location-specific, and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of 12-inch removal/disposal and backfill of the affected sediment is high. The COCs will no longer present any risk to benthic invertebrates in Jefferson Canal.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments, however, through excavation of the Canal, mobility is eliminated and volume is reduced.

Short-term effectiveness

Short-term effectiveness of the 12-inch removal/disposal and backfill alternative depends upon duration of implementation. This includes standard construction mobilization, staging of equipment, dewatering and removal of COC-affected sediment. The areas of excavation will be replaced with unaffected sediment that will be staged at the Site. Additionally, care will be taken to install best management practices such as silt curtains to trap any affected sediment that may become resuspended in the water column by the excavation process.

Implementability

The 12-inch removal/disposal alternative is highly implementable. Materials, equipment, and technology are readily available. Timing is not critical because the areas to be remediated do not require diversion; however, a low water level would be beneficial to the process. The removed sediment will be dewatered in a controlled manner and removed to an appropriate facility for disposal. Clean fill will need to be transported and placed to maintain the hydraulic capacity of the canal. This fill will be anchored with a biodegradable geogrid and a vegetatively impregnated sediment control matting for side slope stabilization of the embankments.

5.3.2 JEFFERSON CANAL SPOIL PILE

The spoil pile is located upstream from the Hurricane Protection Levee and downstream from FM 366. The southern limits of the spoil pile abut FM 366 Road, the Lower Neches Valley Authority Canal, and the Kansas City Southern Railroad. The western limit abuts to the overhead Entergy Power lines that extend south to north. Jefferson Canal extends from south to north on the eastern bank of the spoil pile. The area immediately east of Jefferson Canal is heavily vegetated with trees. The Jefferson Canal Spoil Pile was previously vegetated with trees, and during the Tier 2 RI those trees were removed to facilitate preparation of a topographic map and collection of sediment and soil samples. The spoil pile is partially composed of previously dredged material; therefore, it has a high lime content. The ground surface includes several "mounds" of the spoils that are a few feet in height and provide an uneven ground surface. The ground surface elevation is several feet above the groundwater table and drains from west to east into the Jefferson Canal.

Figure 1-5 shows several pipelines that extend south to north and east to west through the Jefferson Canal Spoil Pile. These pipelines were considered during the evaluation of all remedial alternatives for the Jefferson Canal Spoil Pile AOI. In addition, refer to Appendix A for information regarding the pipelines at or near this AOI. Thiessen polygons for Jefferson Canal Spoil Pile AOI are shown on Figure 5-2. Individual analysis of remedial alternatives for Jefferson Canal Spoil Pile AOI are summarized in Table 5-2.

5.3.2.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risks associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between ROCs and the soil, nor does it reduce the volume or mobility of the COC-affected soils identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility, or volume of COCs, nor does it prevent or reduce risk of exposure to ROCs.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.2.2 ALTERNATIVE 2A – CONTAINMENT – WITHOUT EXCAVATION: COMPOSITE CAP

The containment alternative is feasible for the Jefferson Canal Spoil Pile AOI, because it would isolate the COC-affected soils from the environment. Composite cap composition and thickness will be designed to prevent infiltration of rainwater and erosion by surface runoff. For Alternative 2A, the entire spoil pile will be capped with a composite cap.

Overall Protection of the Environment

A composite cap as defined in Section 4.2.3 provides a disruption of the pathway between COCs and the receptors.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs applicable and relevant for the Site.

Long-term effectiveness and permanence

The composite cap alternative provides long-term effectiveness for the protection of ecological receptors and the reduction of any risks associated with exposure to the COCs, by providing a barrier between all COC-affected soil and the environment.

Reduction of toxicity, mobility, and volume

This alternative eliminates the mobility of the COC-affected soils. Volume of COC-affected soil is not reduced. Toxicity may be reduced depending on concentration per unit volume following cap implementation, and amendment materials in the composite cap.

Short-term effectiveness

The composite cap alternative provides short-term effectiveness for the protection of ecological receptors and the reduction of any risks associated with exposure to COCs, dependent upon duration of implementation. This includes time for standard construction mobilization, staging of equipment, transportation, and placement of cap materials.

Implementability

The composite cap alternative is highly implementable. Materials and equipment are readily available. No COC-affected soil will be excavated. The capping material will be transported to the Site and anchored in place. The composite cap is considered impervious to rain water infiltration and erosion resistant.

5.3.2.3 ALTERNATIVE 2B – PARTIAL CONTAINMENT – WITHOUT EXCAVATION: COMPOSITE CAP

The containment alternative is feasible for the Jefferson Canal Spoil Pile AOI, because it would isolate the COC-affected soils from the environment. For Alternative 2B, a set-back or servitude will not be disturbed within 25 feet of the pipelines extending below the Spoil Pile. For the remaining area of the AOI, the soil surface will be graded and composite cap composition and thickness will be designed to prevent infiltration of rainwater and erosion by surface runoff.

Overall Protection of the Environment

A composite cap as defined in Section 4.2.3 provides a disruption of the pathway between COCs and the receptors, applicable for all areas of the Spoil Pile AOI outside of the pipeline servitude.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs applicable and relevant for the Site.

Long-term effectiveness and permanence

The composite cap alternative provides long-term effectiveness for the protection of ecological receptors and the reduction of any risks associated with exposure to the COCs for all areas of the Spoil Pile AOI outside of the pipeline servitude.

Reduction of toxicity, mobility, and volume

The clay or composite cap eliminates the mobility of the COC-affected soils. Volume of affected soils is not reduced, and reduction of toxicity is dependent on components of the composite cap. For Alternative 2B, the servitude will not be capped, leaving 30 percent of COC-affected soils in place with no reduction of mobility, volume, or toxicity.

Short-term effectiveness

The composite cap alternative provides short-term effectiveness for the protection of ecological receptors and the reduction of any risks associated with exposure to COCs for all areas of the Spoil Pile AOI outside of the pipeline servitude..

Implementability

The composite cap alternative is highly implementable; materials and equipment are readily available. Implementability is reduced by the pipeline servitude, which will require the composite cap to be installed as multiple pieces. Thirty percent of the AOI will be left undisturbed, and 70 percent will be covered by an impervious and erosion resistant composite cap. The capping material will be transported to the Site and anchored in place.

5.3.2.4 ALTERNATIVE 3A – PARTIAL 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: COMPOSITE CAP

The 12-inch removal/disposal and containment: composite cap alternative will include excavation of soil using standard excavation equipment because the Jefferson Canal Spoil Pile is easily accessible. For Alternative 3A, a set-back or servitude will not be disturbed within 25 feet of the pipelines extending below the spoil pile during the 12-inch removal of soil by excavator. The entire spoil pile will then be capped with a composite cap. Excavated material will be transported to an appropriate off-Site disposal facility. During the remedial design, the EPA will seek permission to allow the pipelines to remain in place.

Overall Protection of the Environment

This alternative serves to protect the environment through partial elimination of the COCs and a permanent disruption of the pathway between receptors and the COC-affected soils. The COC-affected soils will be partially removed from the Site and disposed in an appropriate off-Site waste facility. A cap with 12 inches of clay and 12 inches of topsoil will cover the entire spoil pile after removal outside the pipeline servitude is completed. This cap would be anchored and stabilized.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of removal/disposal and containment of the affected sediment is high. The COCs will be isolated from the receptors and the area will be stabilized. Infiltration from rain events and erosion will be prevented by the cap and established vegetation.

Reduction of toxicity, mobility, and volume

This alternative eliminates the mobility of COC-affected soil through excavation of 70 percent of the area of the spoil pile and cap placement over the entire spoil pile. Volume is reduced by the 12-inch removal of soil outside the pipeline servitude, and toxicity may be reduced depending on concentration per unit volume of sediment remaining and amendment materials in the composite cap.

Short-term effectiveness

The partial 12-inch removal/disposal and containment alternative, in correspondence to duration of implementation, provides short-term effectiveness for the protection of ecological receptors, and the reduction of any risks associated with exposure to COCs.

Implementability

The partial 12-inch removal/disposal and containment alternative is highly implementable. Materials and equipment are readily available. Standard excavation equipment will be used to remove the first 12 inches of excavated COC-affected soil outside the pipeline servitude and facilitate transportation to an approved off-Site disposal facility. The capping material will be delivered to the Site and anchored in place. The composite cap is considered impervious to rain water infiltration and erosion resistant.

5.3.2.5 ALTERNATIVE 3B – PARTIAL 12-INCH REMOVAL/DISPOSAL AND PARTIAL CONTAINMENT: COMPOSITE CAP

The partial 12-inch removal/disposal and partial containment: composite cap alternative will include excavation of soil using standard excavation equipment because the Jefferson Canal Spoil Pile is easily accessible. For Alternative 3B, a set-back or servitude will not be disturbed within 25 feet of the pipelines extending below the Spoil Pile. For the remaining area of the AOI, 12 inches of soil will be removed by an excavator and replaced with a composite cap. Excavated material will be transported to an appropriate off-Site facility.

Overall Protection of the Environment

This alternative serves to protect the environment through partial elimination of the COCs and a permanent disruption of the pathway between receptors and the COC-affected soils. The COC-affected soils will be partially removed from Site and disposed in an appropriate off-Site waste facility. A cap with 12 inches of clay and 12 inches of topsoil will be anchored and stabilized to replace excavated soil outside of the pipeline servitude.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of partial removal/disposal and partial containment of the affected soil is high. For all areas of the Spoil Pile AOI outside of the pipeline servitude, the COCs will be isolated from the receptors and the area will be stabilized. Infiltration from rain events and erosion will be prevented by the cap and established vegetation.

Reduction of toxicity, mobility, and volume

Removal and disposal reduces volume and mobility of COC-affected soils, and the clay or composite cap eliminates mobility. Reduction of toxicity is dependent on ratio of soil removed and components of the composite cap. For Alternative 3B, the servitude will not be excavated or capped; leaving 30 percent of COC-affected soils in place with no reduction of mobility, volume, or toxicity.

Short-term effectiveness

The partial 12-inch removal/disposal and partial containment alternative, in correspondence to duration of implementation, provides short-term effectiveness for the protection of ecological receptors, and the reduction of any risks associated with exposure to COCs for all areas of the Spoil Pile AOI outside of the pipeline servitude.

Implementability

The partial 12-inch removal/disposal and partial containment alternative is highly implementable. Materials and equipment are readily available. Implementability is reduced by the pipeline servitude, which will require the implementation area to be divided into multiple subsections, thus increasing fencing, staking, and other administrative controls. Thirty percent of the AOI will be left undisturbed, and 70 percent excavated 12 inches and covered by an impervious and erosion resistant composite cap. The capping material will be delivered to the Site and anchored in place.

5.3.3 FORMER STAR LAKE

The Former Star Lake AOI includes the area of the former Star Lake southwest of Atlantic Road and southeast of Star Lake Canal. The Former Star Lake AOI in plan view has the shape of two rectangles and the Star Lake Canal extends from southwest to northeast through the former Star Lake and both rectangles abut northeast to Atlantic Road. The rectangle to the southeast of Star Lake Canal is approximately 300 feet in the northwest to southeast direction and 800 feet in the southwest to northeast direction. The rectangle to the northwest of Star Lake Canal extends approximately 800 feet in the southwest to northeast direction and 800 feet in the southeast to northwest direction. The Former Star Lake AOI is a marsh or wetland area with a silty bottom and wetland vegetation throughout. The bottom is generally 1 foot to 2 feet below tide and tidally inundated. Thiessen polygons for Former Star Lake AOI are shown on Figure 5-3.

All pipelines at or near the Former Star Lake AOI will be taken into consideration for all remedial alternatives developed for this AOI, Refer to Appendix A to view pipelines in the vicinity of the Former Star Lake AOI. Thiessen polygons for Former Star Lake AOI are shown on Figure 5-3. Individual analysis of remedial alternatives for Former Star Lake AOI are summarized in Table 5-3.

5.3.3.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between benthic invertebrates and the sediment, nor does it reduce the volume or mobility of the COC-affected sediments identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility or volume of COCs, nor does it prevent or reduce risk of exposure to benthic organisms.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.3.2 ALTERNATIVE 2 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: IMPERMEABLE CAP

The 12-inch removal/disposal and containment alternative is a feasible option for polygons located in the Former Star Lake AOI (Polygons that correspond to sample numbers: SL-6, SL-7, SL-9, SL-10).

Overall Protection of the Environment

The 12-inch removal/disposal and containment alternative protects the environment through the elimination of the COC-affected sediment. This alternative also provides a permanent disruption of the pathway between receptors and the COC-affected sediments. Cap installation will restore the bottom of the Former Star Lake AOI to the pre-excavation depth. An impermeable cap will provide a barrier between the benthic invertebrates and COC-affected sediment, and resist erosion from an inundated drainage canal. The hydraulic capacity or the sediment topography of the canal will not be modified by the cap design.

Compliance with the ARARs

This alternative will be designed to comply with chemical-specific, location-specific, and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of the 12-inch removal/disposal and containment alternative is high. The pathway between the COC-affected sediments and benthic organisms will be permanently interrupted, and the area stabilized from erosion and bioturbation by benthic invertebrate burrowing and erosion.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments, however, through excavation of the Former Star Lake AOI, mobility is eliminated and volume is reduced. The impermeable cap will further isolate any remaining affected sediment, and reduce erosion, eliminating mobility of the COCs to the benthic environment.

Short-term effectiveness

The removal/disposal and containment alternative provides short-term effectiveness, in correspondence to duration of implementation, for the protection of ecological receptors, and the reduction of any risks associated with exposure to COCs.

Implementability

The 12-inch removal/disposal and containment alternative is highly implementable. Materials and equipment are readily available. Standard excavation equipment will be used to remove COC-affected sediment and facilitate transportation to an approved disposal facility. The capping material will need to be delivered to the Site and anchored in place. The installed cap is considered erosion resistant and impervious to both infiltration and burrowing of benthic organisms.

5.3.3.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH SOIL CAP

The 12-inch removal/disposal and containment alternative with a 12-inch soil cap, is a feasible option for polygons located in the Former Star Lake AOI (polygons that correspond to sample numbers: SL-6, SL-7, SL-9, SL-10).

Overall Protection of the Environment

The 12-inch removal/disposal and containment alternative with a 12-inch soil cap, provides overall protection through the elimination of the pathway between COC-affected sediment and the environment. Installation of a soil cap will restore the bottom of the Former Star Lake AOI to the pre-excavation depth, and provide a new benthic habitat. This alternative will be designed not to modify the hydraulic capacity of the Former Star Lake AOI.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of the 12-inch removal/disposal and containment alternative is high. The pathway between the COC-affected sediments and benthic organisms will be permanently interrupted by excavation; bioturbation from benthic invertebrate burrowing and erosion from water movement will be reduced by the soil cap.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments, however, through excavation of the Former Star Lake AOI, mobility is eliminated and volume is reduced. The soil cap somewhat reduces the mobility of any remaining affected sediment to the environment.

Short-term effectiveness

Short-term effectiveness of 12-inch removal/disposal and containment alternative cap depends upon duration of implementation. This includes time for standard construction mobilization, staging of equipment, dewatering and removal of COC-affected sediments. The areas of excavation will be replaced with cap soil that will be staged at the Site.

Implementability

This alternative is highly implementable. Materials, equipment and technology are readily available. Removed sediment will be dewatered in a controlled manor and removed to an appropriate facility for permanent disposal. Cap soil will be placed to maintain the hydraulic intent of the Former Star Lake AOI.

5.3.4 STAR LAKE CANAL

The distance along Star Lake Canal from its origin east of the intersection of Highway 136 and FM 366 to its confluence with the Neches River is approximately 16,500 feet. The Star Lake Canal portion of the AOI for the FS commences at the point of intersection with Jefferson Canal and extends approximately 10,000 feet to the confluence with the Neches River. Immediately northeast of the intersection with the Atlantic Road is the Associated Marine Services, Inc., dock. The channel is approximately 5 feet to 6 feet deep at the intersection with Jefferson Canal and about 20 feet wide with steep side slopes and a silty bottom. Beginning at Atlantic Road, it is about 50 feet wide, and gradually increases in width towards the Neches River to a width of about 150 feet to its confluence with the Neches River. The average depth is about 10 feet near the dock and 20 feet near the confluence with the Neches River. The canal is tidally influenced and navigable. Thiessen polygons for Star Lake Canal AOI are shown on Figure 5-4.

All pipelines at or near the Star Lake Canal AOI will be taken into consideration for all remedial alternatives developed for this AOI, Refer to Appendix A to view pipelines in the vicinity of the Star Lake Canal AOI. Thiessen polygons for Star Lake Canal AOI are shown on Figure 5-4. Individual analysis of remedial alternatives for Star Lake Canal AOI are summarized in Table 5-4.

5.3.4.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between benthic invertebrates and the sediment, nor does it reduce the volume or mobility of the COC-affected sediments identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility or volume of COCs, nor does it prevent or reduce risk of exposure to benthic organisms.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.4.2 ALTERNATIVE 2 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: IMPERMEABLE CAP

The 12-inch removal/disposal and containment alternative is a feasible option for polygons located in the Star Lake Canal AOI (Polygons that correspond to sample numbers: SLC-6 and SLC-11). Hydraulic excavation is the preferred removal technology for the navigable portion of the Star Lake Canal (the polygon associated with sample number SLC-11).

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. This alternative serves to protect the environment through the partial elimination of the COC-affected sediment. This process provides a permanent disruption of the pathway between receptor organisms and COC-affected sediments. The sediment would be partially removed from the Site and disposed in an appropriate waste facility. An impermeable cap will replace the removed sediment. The impermeable cap will be designed to provide isolation between the affected sediments and benthic invertebrates and to resist erosion. The hydraulic capacity of the canal will not be modified by this alternative.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of excavation/disposal and containment of the affected sediment is high. The pathway between the COC-affected sediments and benthic organisms will be permanently interrupted, and the area stabilized from erosion and bioturbation by benthic invertebrate burrowing.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments, however, through excavation of the Star Lake Canal AOI, mobility is eliminated and volume is reduced. The impermeable cap will further isolate any remaining affected sediment, and reduce erosion, eliminating mobility of the COCs to the benthic environment.

Short-term effectiveness

Excavation, disposal, and construction of the impermeable cap will provide short-term effectiveness, in correspondence with duration of implementation, for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Implementability

The removal/disposal and containment alternative is highly implementable. Materials and equipment are readily available. Standard excavation equipment will be used to remove COC-affected sediment and facilitate transportation. Capping material will be delivered to the Site and put in place. The excavated sediment will need to be dewatered and disposed in an authorized disposal facility. Sediment and erosion control will be in place to prevent any COC-affected sediments from becoming resuspended and entering the waterway during excavation and placement of the impermeable cap. Hydraulic capacity will be maintained for this navigable waterway and a Section 10 Permit will be in place.

5.3.4.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: ARMORED CAP

The 12-inch removal/disposal and containment alternative with an armored cap, is a feasible option for polygons located in the Star Lake Canal AOI (polygons that correspond to sample numbers: SLC-6 and SLC-11).

Overall Protection of the Environment

The removal/disposal and containment alternative with an armored cap, serves to protect the environment by removal of COC-affected sediments from the benthic environment. This armor cap reduces erosion of the loose bayou sediment, and provides a new benthic habitat.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of this alternative is high. The path between the COC-affected sediments and the environment will be disrupted by excavation; erosion will be continually inhibited by the armor cap.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments, however, through excavation of the Star Lake Canal AOI, mobility is eliminated and volume is reduced. The armor cap will reduce the mobility of the any remaining COCs affected sediments by reducing erosion.

Short-term effectiveness

Short-term effectiveness of the removal/disposal and containment alternative depends upon duration of implementation. This includes time for standard construction mobilization, staging of equipment, dewatering, and removal of COC-affected sediment. The areas of excavation will be replaced with fill, and armor cap materials will be staged at the Site. Additionally care will be taken to implement best management practices such as curtains, to trap any affected sediment that may become resuspended in the water column by the excavation process or placement of backfill and cap materials.

Implementability

This alternative is highly implementable. Materials, equipment and technology are readily available. Removed sediment will be dewatered in a controlled manor and removed to an appropriate facility for permanent disposal. Armor cap materials will be placed to maintain the hydraulic intent of the Star Lake Canal AOI.

5.3.5 GULF STATES UTILITY CANAL

The Gulf States Utility Canal extends parallel to the Star Lake Canal and is shallow, with side slopes at 4 horizontal to 1 vertical (4:1) or less. The canal was initially created to construct the overhead utility lines and is tidally inundated. Thiessen polygons for Gulf States Utility Canal AOI are shown on Figure 5-5.

All pipelines at or near the Gulf States Utility Canal AOI will be taken into consideration for all remedial alternatives developed for this AOI, Refer to Appendix A to view pipelines in the vicinity of the Gulf States Utility Canal AOI. Thiessen polygons for Gulf States Utility Canal AOI are shown on Figure 5-5. Individual analysis of remedial alternatives for the Gulf States Utility Canal AOI are summarized in Table 5-5.

5.3.5.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between benthic invertebrates and the sediment, nor does it reduce the volume or mobility of the COC-affected sediments identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility or volume of COCs, nor does it prevent or reduce risk of exposure to benthic organisms.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs**.**

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.5.2 ALTERNATIVE 2 – CONTAINMENT: COMPOSITE CAP

Within the Gulf States Utility Canal, the containment: composite cap alternative will be applied to the polygon associated with sample number GSUC-7.

Overall Protection of the Environment

The containment alternative using a composite cap serves to protect the environment by isolation of COC-affected sediments from benthic invertebrates and the environment. This alternative would reduce erosion of the canal bottom and provide a new benthic habitat.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of a composite cap is high. The migration of COCs from erosion and the bioturbation from the burrowing of benthic invertebrates will be continually inhibited.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity or volume; however, the composite cap reduces the mobility of the constituents by providing a barrier between the affected sediment and the environment.

Short-term effectiveness

Short-term effectiveness of the impermeable cap alternative depends upon duration of implementation. This includes standard construction, mobilization and staging of equipment, cap material placement, and stabilization of the area following cap installation.

Implementability

The containment alternative is highly implementable. Materials, equipment, and technology are readily available. Timing is not critical because the canal is not continually inundated, and does not require any water diversion. The cap will serve to anchor the sediment, and erosion control matting will stabilize the embankment.

5.3.5.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: ARMORED CAP

Within the Gulf States Utility Canal, the 12-inch removal/disposal and containment alternative will be applied to the polygon associated with sample number GSUC-7.

Overall Protection of the Environment

This alternative serves to protect the environment by permanent elimination of the pathway between COC-affected sediments and benthic organisms, through excavation of the affected sediment and placement of a cap to isolate remaining sediment. The use of an armored cap following excavation will reduce erosion of the canal bottom, promote the creation of a new benthic environment, and provide isolation from interaction with any remaining COC-affected sediment.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of removal/disposal and containment of the affected sediment is high. The COC-affected sediment will be permanently removed and the canal stabilized from erosion caused by intermittent tidal influx and rain events.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments; however, through excavation of the Gulf States Utility Canal AOI, mobility is eliminated and volume is reduced. The armor cap will reduce the mobility of the any remaining COCs affected sediments by reducing erosion.

Short-term effectiveness

Short-term effectiveness of the 12-inch removal/disposal and containment alternative depends upon duration of implementation. This includes time for standard construction mobilization, staging of equipment, dewatering and removal of COC-affected sediments. The areas of excavation will be replaced with cap materials that will be staged at the Site. Sediment and erosion control measures will be implemented to prevent COC-affected sediment from being redistributed in the area by the excavation, dewatering, or cap placement process.

Implementability

This alternative is highly implementable. Materials, equipment and technology are readily available. Timing is not critical because the canal is infrequently inundated with water and does not require water diversion. Removed sediment will be dewatered in a controlled manor and removed to an appropriate facility for permanent disposal. Cap material, will be placed to maintain the hydraulic capacity of the canal. The cap will serve to anchor any remaining sediment. Erosion control matting will stabilize the embankments.

5.3.5.4 ALTERNATIVE 4 – 12-INCH REMOVAL/DISPOSAL

Within the Gulf States Utility Canal, the 12-inch removal/disposal alternative will be applied to the polygon associated with sample number GSUC-7.

Overall Protection of the Environment

This alternative serves to protect the environment through permanent elimination of the pathway between COC-affected sediments and benthic organisms through removal/disposal.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of removal/disposal of the affected sediment is high. The COCs would no longer present a risk to benthic invertebrates in the Gulf States Utility Canal.

Reduction of toxicity, mobility, and volume

This alternative does not reduce toxicity of the COC-affected sediments; however, through excavation of the Gulf States Utility Canal AOI, mobility is eliminated and volume is reduced.

Short-term effectiveness

Short-term effectiveness of the removal/disposal alternative depends upon duration of implementation. This includes standard construction mobilization, staging of equipment, and the removal and dewatering of COC-affected sediment. Sediment and erosion control measures must be implemented to prevent COC-affected sediment from being redistributed by the excavation.

Implementability

This alternative is highly implementable. Materials, equipment and technology are readily available. Timing is not critical because the canal is infrequently inundated with water and does not require water diversion. Removed sediment will be dewatered in a controlled manor and removed to an appropriate facility for permanent disposal. Vegetation impregnated sediment and erosion control matting will provide immediate stabilization of the excavated area and adjacent embankments.

5.3.6 MOLASSES BAYOU WATERWAY

The Molasses Bayou Waterway is a narrow, shallow, heavily vegetated meandering reach of slow moving water often overgrown with reeds and other vegetation. The bayou is approximately 2 feet to 3 feet in depth with a bed consisting of 2 feet to 3 feet of fine-grained sediment and is tidally inundated. The cross section of the bayou varies from 3 feet to 30 feet in width. The area is accessible by small boat. The waterway is influenced by tidal flow from the Neches River. Thiessen polygons for Molasses Bayou Waterway AOI are shown on Figure 5-6.

All pipelines at or near the Molasses Bayou Waterway AOI will be taken into consideration for all remedial alternatives developed for this AOI, Refer to Appendix A to view pipelines in the vicinity of the Molasses Bayou Waterway AOI. Thiessen polygons for the Molasses Bayou Waterway AOI are shown on Figure 5-6. Individual analysis of remedial alternatives for the Molasses Bayou Waterway AOI are summarized in Table 5-6.

5.3.6.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between benthic invertebrates and the sediment, nor does it reduce the volume or mobility of the COC-affected sediments identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility or volume of COCs, nor does it prevent or reduce risk of exposure to benthic organisms.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.6.2 ALTERNATIVE 2 – MONITORED NATURAL RECOVERY (MNR)

Monitored Natural Recovery (MNR) will be applied to the Molasses Bayou Waterway polygons (Polygons) that correspond to sample numbers: MB-10, MB-14, MB-18/MB-18R, MB-21, MB-24, MB-49, MB-52, MB-54, MB-60, and MB-61).

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. The MNR alternative lowers the risk of interaction between benthic invertebrates and the sediment very gradually. Overall protection of the environment depends upon the rate of naturally driven degradation and dispersion processes.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The MNR alternative provides a moderate level of long term effectiveness for the protection of ecological receptors and the reduction of risks associated with exposure to COCs. As natural processes occur over time, MNR provides a greater degree of effectiveness by slowly reducing the pathway between the COCs and the environment. Long-term effectiveness would be monitored through a 10-year sampling program.

Reduction of toxicity, mobility, and volume

The MNR alternative reduces the toxicity of COC-affected sediments by optimizing the natural biological processes in Molasses Bayou to break down PAHs and PCBs. The mobility of heavy metals may be reduced over time as the metals sorb to clays present in the existing sediment. The current within Molasses Bayou Waterway is weak, thus reduction of sediment volume by dispersion or reduction of mobility by placement of new sediment would occur very slowly.

Short-term effectiveness

The MNR alternative provides a very low level of short-term effectiveness since it depends upon the occurrence of natural processes over time. Implementation provides no immediate protection of ecological receptors or reduction of risks associated with exposure to COCs. Implementation does not cause bioturbation of COC-affected sediments or marsh disturbance which may occur with other alternatives that have more active implementation.

Implementability

Implementability of MNR is high within the Molasses Bayou Waterway because little action is taken to optimize the naturally occurring processes. Heavy equipment, difficult to maneuver in areas surrounding the bayou, is not necessary. Administrative responsibilities are minimal, consisting of those associated with a 10-year sampling program for long term monitoring.

5.3.6.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: ARMORED CAP

The removal/disposal and containment alternative is considered feasible within the Molasses Bayou Waterway polygons (Polygons that correspond to sample numbers: MB-10, MB-14, MB-18/MB-18R, MB-21, MB-24, MB-49, MB-52, MB-54, MB-60, and MB-61).

Overall Protection of the Environment

The removal/disposal and containment alternative using armored cap, provides overall protection by isolation of COC-affected sediments from benthic invertebrates and the environment. This alternative will reduce erosion of the soft bayou sediments, and provide a new benthic habitat.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site. .

Long-term effectiveness and permanence

The long-term effectiveness and permanence of removal, disposal, and an armor cap is high. Excavation will permanently interrupt the pathway between COC-affected sediments and receptors, and the migration of any remaining COCs would be continually inhibited by the placement of an armored cap.

Reduction of toxicity, mobility, and volume

Toxicity may be reduced depending on the concentration per unit volume remaining in place; however, volume is reduced by the amount of sediment excavated from the Site. Mobility is also reduced by the use of the erosion resistant cap.

Short-term effectiveness

Short-term effectiveness of the removal/disposal and containment alternative depends upon duration of implementation. This includes time for standard construction mobilization, staging of equipment, dewatering, and removal of COC-affected sediment. The areas of excavation will be replaced with fill, and cap materials that will be staged at the Site. Additionally, care will be taken to implement best management practices such as curtains to trap any affected sediment that may become resuspended in the water column by the excavation process, or placement of backfill and cap materials.

Implementability

The removal/disposal and containment alternative has a low level of implementability within the Molasses Bayou Waterway. Dredging and excavation both require a high degree of accessibility and generate a large volume of sediment for disposal. Heavy equipment access and the preparation of staging and dewatering areas will cause damage to portions of the shallow and narrow bayou as well as the adjacent wetlands. Transportation of cap materials requires a high degree of accessibility and there is no convenient location for staging of cap materials. Administrative responsibilities include permitting and coordination of off-Site transportation for removed sediment, and application for a Section 10 permit to work in navigable waters. The hydraulic capacity of the waterway or the soil/water topography will not be modified.

5.3.7 MOLASSES BAYOU WETLAND

The Molasses Bayou Wetland is a heavily vegetated marsh, with water approximately 1 foot to 2.5 feet in depth underlain by 2 feet to 3 feet of fine-grained sediment. The wetland has been silted in over time and is choked with vegetation. This wetland is tidally inundated, and the wetland is accessible by small boat. Thiessen polygons for Molasses Bayou Wetland AOI are shown on Figure 5-7.

All pipelines at or near the Molasses Bayou Wetland AOI will be taken into consideration for all remedial alternatives developed for this AOI, Refer to Appendix A to view pipelines in the vicinity of the Molasses Bayou Wetland AOI. Thiessen polygons for the Molasses Bayou Wetland AOI are shown on Figure 5-7. Individual analysis of remedial alternatives for the Molasses Bayou Wetland AOI are summarized in Table 5-7.

5.3.7.1 ALTERNATIVE 1 – NO ACTION

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. A No Action alternative does not lower the risk of interaction between benthic invertebrates and the sediment, nor does it reduce the volume or mobility of the COC-affected sediments identified.

Compliance with the ARARs

Since no remedial action is taken, the No Action alternative would not engage the chemical- , location- , or action-specific ARARs.

Long-term effectiveness and permanence

The No Action alternative provides no long-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Reduction of toxicity, mobility, and volume

The No Action alternative does not reduce toxicity, mobility or volume of COCs, nor does it prevent or reduce risk of exposure to benthic organisms.

Short-term effectiveness

The No Action alternative provides no short-term effectiveness for the protection of ecological receptors or the reduction of any risks associated with exposure to COCs.

Implementability

The No Action alternative does not require implementation or regulatory oversight.

5.3.7.2 ALTERNATIVE 2 – MONITORED NATURAL RECOVERY (MNR)

MNR is considered feasible within the Molasses Bayou Wetland polygons (polygons that correspond to sample numbers: MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, and MB-63).

Overall Protection of the Environment

Potential ecological receptor risk associated with current Site conditions were identified in the BERA. The MNR alternative lowers the risk of interaction between benthic invertebrates and the sediment very gradually. Overall protection of the environment depends upon the rate of naturally driven degradation and dispersion processes.

Compliance with the ARARs

The MNR alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The MNR alternative provides a moderate level of long term effectiveness for the protection of ecological receptors and the reduction of risks associated with exposure to COCs. As natural processes occur over time, MNR provides a greater degree of effectiveness by slowly reducing the pathway between the COCs and the environment. Long-term effectiveness would be monitored through a 10-year sampling program.

Reduction of toxicity, mobility, and volume

The MNR alternative reduces the toxicity of COC-affected sediments by optimizing the natural biological processes in Molasses Bayou Wetland to break down PAHs and PCBs. The mobility of heavy metals may be reduced over time as the metals sorb to clays present in the existing sediment. The current within Molasses Bayou Wetland is weak and is restrained by vegetation, thus reduction of sediment volume by dispersion, or reduction of mobility by placement of new sediment would occur very slowly.

Short-term effectiveness

The MNR alternative provides a very low level of short-term effectiveness since it depends upon the occurrence of natural processes over time. Implementation provides no immediate protection of ecological receptors or reduction of risks associated with exposure to COCs. Implementation does not cause redistribution of COC-affected sediments as may occur with alternatives that are more active. MNR does not cause any disturbance of the marsh as will occur with the use of heavy equipment.

Implementability

Implementability of MNR is high within the Molasses Bayou Wetland because little action is taken to optimize the naturally occurring processes. Heavy equipment, difficult to maneuver in areas surrounding the bayou, is not necessary. Administrative responsibilities are minimal, consisting of those associated with a 10-year sampling program for long term monitoring.

5.3.7.3 ALTERNATIVE 3 - CONTAINMENT: COMPOSITE CAP

Overall Protection of the Environment

The composite cap alternative serves to protect the environment by isolation of COC-affected sediments from benthic invertebrates and the environment. This alternative will reduce erosion of the soft bottom, and provide a new benthic habitat.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs applicable and relevant for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of a composite cap is high. The migration of COCs from erosion and bioturbation from the burrowing of benthic invertebrates will be continually inhibited.

Reduction of toxicity, mobility, and volume

A composite cap will reduce the mobility of the constituents by providing a barrier between the affected sediment and the ecological system. The toxicity and volume of the COCs will not be reduced by the installation of the composite cap.

Short-term effectiveness

Short-term effectiveness of the composite cap alternative depends upon duration of implementation. This includes time for specialized construction mobilization, staging of equipment and cap materials, and stabilization of the area following cap installation.

Implementability

The containment alternative has a low level of implementability within the Molasses Bayou Wetland. The wetland has a low degree of accessibility, which impedes delivery of cap materials and equipment. Delivery and operations will damage portions of the wetlands. The cap must be anchored, but the loose sediment within the wetland is not conducive to accepted anchoring methods. No convenient location exists for staging of cap materials. Administrative responsibilities would permit for disturbance of wetlands.

5.3.7.4 ALTERNATIVE 4 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: ARMORED CAP

Overall Protection of the Environment

The removal/disposal and containment alternative using an armored cap serves to protect the environment through permanent elimination of the pathway between COC-affected sediments and benthic organisms, through excavation. Placement of armored cap following removal would reduce erosion of the wetland floor and promote the creation of a new benthic environment.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of removal/disposal and containment of the affected sediment is high. The COCs will no longer present a risk to benthic invertebrates in the Molasses Bayou Wetland. The long-term effectiveness of the armored cap is also high, because it continually resists erosion.

Reduction of toxicity, mobility, and volume

Toxicity may be reduced depending on the concentration per unit volume remaining in place; however, volume is reduced by the amount of sediment excavated from the Site. Mobility is also reduced by the use of the erosion resistant cap.

Short-term effectiveness

Short-term effectiveness of the removal/disposal and containment alternative depends upon the duration of implementation. This includes time for standard construction mobilization, staging of equipment, and the removal and dewatering of COC-affected sediment. The areas of excavation will be replaced with unaffected sediment, and cap materials will be staged at the Site. Additionally, care will be taken to implement best management practices such as curtains to trap any affected sediment that may become resuspended in the water column by the excavation process or by the placement of backfill and cap materials.

Implementability

The removal/disposal and containment alternative has a low level of implementability within the Molasses Bayou Wetland. Dredging and excavation both require a high degree of accessibility and generate a large volume of sediment for disposal. Heavy equipment access and the preparation of staging and dewatering areas may cause damage to portions of the marsh. Administrative responsibilities will include permitting and coordination of off-Site transportation for removed sediment and for disturbance of wetlands.

5.3.7.5 ALTERNATIVE 5 – 12-INCH REMOVAL/DISPOSAL

Overall Protection of the Environment

This alternative serves to protect the environment by permanent elimination of the pathway between COC-affected sediments and benthic organisms, through removal/disposal.

Compliance with the ARARs

This alternative will be designed to comply with chemical- , location- , and action-specific ARARs for the Site.

Long-term effectiveness and permanence

The long-term effectiveness and permanence of removal/disposal of the affected sediment is high. The COC-affected sediment would no longer present a risk to benthic invertebrates in the Molasses Bayou Wetland.

Reduction of toxicity, mobility, and volume

This alternative reduces the toxicity, mobility and volume of the constituents by removal of COC-affected sediment from the ecological system.

Short-term effectiveness

Short-term effectiveness of the removal/disposal alternative depends upon duration of implementation. This includes time for standard construction mobilization, staging of equipment, removal, and dewatering of COC-affected sediment. Sediment and erosion control measures will be implemented to prevent COC-affected sediment from being redistributed by the excavation or dewatering process.

Implementability

The removal/disposal alternative has a low level of implementability within the Molasses Bayou Wetland. Dredging and excavation both require a high degree of accessibility and generate a large volume of sediment for disposal. Heavy equipment access and the preparation of staging and dewatering areas may cause damage to portions of this shallow wetland. Administrative responsibilities would include permitting and coordination of off-Site transportation for removed sediment and for the disturbance of wetlands.

6.0 COST

The FS cost estimates are estimates developed to allow comparison of alternatives with respect to project cost and other criteria. A cost estimate is a calculation of the estimated quantities of various items of work, and the expenses likely to be incurred. The total of these probable expenses to be incurred on the work is known as the estimated cost of the work. A reliable estimate of costs will affect decisions in selection of a preferred remedial alternative.

Several techniques may be used to estimate the cost of environmental remediation. This FS uses the unit cost method where work is divided into as many operations or items as are required. A unit of measurement is determined. The total quantity of work under each item is apportioned into a proper unit of measurement. The total cost per unit quantity of each item is determined by estimation, by collection of vendor price quotations, or use of citation of publisher unit costs. The total cost for the item is found by multiplying the cost per unit quantity by the number of units. For example, while estimating the cost of a building, the quantity of brickwork in the building would be measured in cubic meters. The total cost (which includes cost of materials, labor, plant, overheads and profit) per cubic meter of brickwork would be found; this unit cost, multiplied by the number of cubic meters of brickwork in the building, would give the estimated cost of brickwork. This method has the advantage that the unit costs on various jobs can be readily compared and that the total estimate can easily be corrected for variations in quantities.

The project cost information is evaluated to compare remedial alternatives and to evaluate the comparison among alternatives. Estimated costs for each alternative were prepared on a unit-cost basis. Material, equipment, and labor quantities specific to each alternative were each assigned a unit cost. For each alternative, the extended cost of each quantity listed in the alternative was determined by multiplication of that quantity by the corresponding unit cost, and extended cost values were then summed to develop the total estimated cost of each alternative. Costs associated with each alternative were estimated for initial capital expenditures at project commencement and for annual operation and maintenance (O&M) expenditures, as appropriate for each alternative. Annual O&M costs also include monitoring costs, as applicable. For each alternative, an equivalent net present value (NPV) of estimated annual O&M costs was developed. The estimated NPV of annual O&M costs for each alternative was determined on the basis of an anticipated average annual simple interest rate of 2.8 percent and an estimated project life of 10 years.

Total estimated costs of each alternative evaluated were determined through addition of total initial capital expenditures and total estimated NPV of annual O&M costs. The total estimated cost of each alternative was used for the basis of cost comparison between alternatives within each AOI.

Estimated unit costs presented for each alternative are based on typical values from environmental remediation and engineering projects of similar size and scope, price quotations requested from equipment and service vendors, and other published cost values for CERCLA sites from public-sector and other sources. Where practical, the same unit cost values were used for comparable unit quantities in all alternatives that were compared, so that cost differences between alternatives reflected differences in alternative scope not biased by differences in unit cost for comparable cost items.

Expenditures that occur over different periods were analyzed using the present-worth analysis, which discounts all future costs to a base year. Present-worth analysis allows the cost of remedial action alternatives to be compared on the basis of a single figure which represents the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. Assumptions associated with the present-worth calculations include a discount rate of 2.8 percent before taxes and after inflation, cost estimates in the planning years in constant dollars, a 10-year period for O&M, and one year of construction to implement the remedy.

The order-of-magnitude cost estimates were prepared using USEPAs *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA, 2000) in conjunction with a standard "unit cost" approach for each alternative. In this approach all alternatives are divided into as many operations or items as are required and a unit of measurement is assigned to each (ton, days, cubic yard, etc.). Total operation cost is then calculated by multiplying the cost per unit quantity by the number of units needed for that defined operation. The summation of all total unit costs is then the total cost for that particular alternative.

All present worth values are based on real discount rates from Appendix C of the Office of Management and Budget (OMB) Circular A-94, Appendix C (revised December 2011). The 10-year discount rate of 2.8 percent was selected since operations and maintenance (O&M) durations are assumed to be over 10 years. This estimate is based on existing conditions. Uncertain market conditions such as, but not limited to, local labor or contractor availability, wages, other work, material market fluctuations, price escalations, and force majeure events, may affect the accuracy of this estimate. The order-of-magnitude cost estimates presented herein provide an accuracy of positive fifty percent to negative thirty percent.

The cost summary tables include capital costs and O&M costs. Capital costs consist of direct and indirect costs. Direct costs include the cost of construction, equipment, land and Site development, labor, transportation, and disposal. Indirect costs include engineering expenses, license or permit costs, and contingency allowances (20 percent). Annual O&M costs are the post-construction costs required for the continued effectiveness of the remedy. Components of annual O&M costs include the cost of maintenance materials and labor, monitoring, and periodic Site reviews.

The cost estimates were prepared based on available Site information at the time of preparation of this submittal and the components of the remedial alternatives discussed in Section 5.0. Additional investigation activities and evaluations will be performed during the remedial design phase. The volume of sediment which requires removal and dewatering or disposal may be refined and cap designs will be finalized based on information collected during the remedial design phase. The cost estimates were prepared using quotes provided by reliable suppliers, technology reference documents, and actual costs from other sediment remediation projects available at the time of preparation of this submittal.

In summary, the cost estimates were prepared in order to compare the different remedial alternatives and disposal options by AOI. The actual cost of the selected remedial alternative will depend on a number of factors which include:

- Final sediment/soil volumes removed
- Final cap design and associated material volumes
- Inclusion of additional emerging technologies that are not currently proposed within the alternatives presented in Section 5.0
- Competitive market conditions
- Actual labor and material costs

Although these factors will affect the cost of each remedial action alternative, they are not expected to affect the relative cost differences between alternatives for the purpose of comparing alternatives. The final costs will likely vary from the estimates presented in this submittal, so funding must be carefully reviewed before specific financial decisions are made or the final budget is established.

Tables 6-1 through 6-7 provide the cost estimates for the remedial alternatives of Jefferson Canal AOI, Jefferson Canal Spoil Pile AOI, Former Star Lake AOI, Star Lake Canal AOI, Gulf States Utility Canal AOI, Molasses Bayou Waterway AOI, and Molasses Bayou Wetlands AOI, respectively.

6.1 COST ESTIMATION ASSUMPTIONS

In the development of cost estimates for all AOIs, assumptions were made. The following is a detailed description of said assumptions.

6.1.1 TOPOGRAPHY

Jefferson Canal: The distance along Jefferson Canal from its origin on the east side of Hogaboom Road south of Farm to Market Road 366 (FM 366) to its confluence with Star Lake Canal, north of the Hurricane Protection Levee, is approximately 4,000 feet. The canal cross-section is trapezoidal with a variable bottom width between 4 feet and 10 feet, with side slopes that are approximately 2 horizontal to 1 vertical (2:1). Most of the length of the canal is unlined; however, a small portion (80 feet) is lined with concrete. Jefferson Canal extends 460 feet beneath Hogaboom Road and continues 2,200 feet to a box culvert that goes beneath FM 366. In this section of the canal, the bottom width in variable ranges between 4 feet and 10 feet with a depth that varies from 6 feet to 10 feet. For the scope of the FS, Jefferson Canal is assumed to be a wetland. Thiessen polygons for Jefferson Canal AOI are shown on Figure 5-1.

Jefferson Canal Spoil Pile: The spoil pile is located upstream from the Hurricane Protection Levee and downstream from FM 366. The southern limits of the spoil pile abut FM 366 Road, the Lower Neches Valley Authority Canal, and the Kansas City Southern Railroad. The western limit abuts to the overhead Entergy Power lines that extend south to north. Jefferson Canal extends from south to north on the eastern bank of the spoil pile. The area immediately east of Jefferson Canal is heavily vegetated with trees. The Jefferson Canal Spoil Pile was previously vegetated with trees, and during the Tier 2 RI those trees were removed to facilitate preparation of a topographic map and collection of sediment and soil samples. The spoil pile is partially composed of previously dredged material; therefore, it has a high lime content. The ground surface includes several "mounds" of the spoils that are a few feet in height and provide an uneven ground surface. The ground surface elevation is several feet above the groundwater table and drains from west to east into the Jefferson Canal.

Figure 1-5 shows several pipelines that extend south to north and east to west through the Jefferson Canal Spoil Pile. These pipelines were considered during the evaluation of all remedial alternatives for the Jefferson Canal Spoil Pile AOI. In addition, refer to Appendix A for information regarding the pipelines at or near this AOI. Thiessen polygons for Jefferson Canal Spoil Pile AOI are shown on Figure 5-2.

Former Star Lake: The Former Star Lake AOI in plan view has the shape of two rectangles and the Star Lake Canal extends from southwest to northeast through the former Star Lake and both rectangles abut northeast to Atlantic Road. The rectangle to the southeast of Star Lake Canal is approximately 300 feet in the northwest to southeast direction and 800 feet in the southwest to northeast direction. The rectangle to the northwest of Star Lake Canal extends approximately 800 feet in the southwest to northeast direction and 800 feet in the southeast to northwest direction. The Former Star Lake AOI is a marsh or wetland area with a silty bottom and wetland vegetation throughout. The bottom is generally 1 foot to 2 feet below tide and tidally inundated. Thiessen polygons for Former Star Lake AOI are shown on Figure 5-3.

Star Lake Canal: The distance along Star Lake Canal from its origin east of the intersection of Highway 136 and FM 366 to its confluence with the Neches River is approximately 16,500 feet. The Star Lake Canal portion of the AOI for the FS commences at the point of intersection with Jefferson Canal and extends approximately 10,000 feet to the confluence with the Neches River. Immediately northeast of the intersection with the Atlantic Road is the Associated Marine Services, Inc., dock. The channel is approximately 5 feet to 6 feet deep at the intersection with Jefferson Canal and about 20 feet wide with steep side slopes and a silty bottom. Beginning at Atlantic Road, it is about 50 feet wide and gradually increases in width towards the Neches River to a width of about 150 feet to its confluence with the Neches River. The average depth is about 10 feet near the dock and 20 feet near the confluence with the Neches River. The canal is tidally influenced and navigable. Thiessen polygons for Star Lake Canal AOI are shown on Figure 5-4.

Gulf States Utility Canal: The Gulf States Utility Canal extends parallel to the Star Lake Canal and is shallow, with side slopes at 4 horizontal to 1 vertical (4:1) or less. The canal was initially created to construct the overhead utility lines and is tidally inundated. Thiessen polygons for Gulf States Utility Canal AOI are shown on Figure 5-5.

Molasses Bayou Waterway: The Molasses Bayou Waterway is a narrow, shallow, heavily vegetated meandering reach of slow moving water often overgrown with reeds and other vegetation. The bayou is approximately 2 feet to 3 feet in depth with a bed consisting of 2 feet to 3 feet of fine-grained sediment and is tidally inundated. The cross section of the bayou varies from 3 feet to 30 feet in width. The area is accessible by small boat. The waterway is influenced by tidal flow from the Neches River. Thiessen polygons for Molasses Bayou Waterway AOI are shown on Figure 5-6.

Molasses Bayou Wetland: The Molasses Bayou Wetland is a heavily vegetated marsh, with water approximately 1 foot to 2.5 feet in depth underlain by 2 feet to 3 feet of fine-grained sediment. The wetland has been silted in over time and is choked with vegetation. This wetland is tidally inundated, and the wetland is accessible by small boat. Thiessen polygons for Molasses Bayou Wetland AOI are shown on Figure 5-7.

6.1.2 AREA AND VOLUME CALCULATIONS

To prepare remedial cost estimates it was necessary to estimate the total area of each AOI and determine an estimation of total volume of material to be removed. The surface area was measured using the Scenario 10b Thiessen Polygons and these areas were then multiplied by an assessment depth to determine the volume. When calculating irregular areas it was assumed that the area had an average width throughout. Molasses Bayou Waterway was assumed to have an average width range of 3 to 30 feet, Jefferson Canal was assumed to have an average width range of 4 to 10 feet. Both canal width assumptions were formulated for the top of the canal during a one foot tide. From these assumptions and calculations the following areas were calculated for each AOI: Jefferson Canal: 0.75 acres, Jefferson Canal Spoil Pile: 10.99 acres (Jefferson Canal Spoil Pile except at pipelines where there is no disturbance: 8.36 acres), Former Star Lake: 5.74 acres, Star Lake Canal: 6.10 acres, Gulf States Utility Canal: 0.36 acres, Molasses Bayou Waterway: 1.58 acres, Molasses Bayou Wetlands: 34.89 acres.

6.1.3 EXCAVATION, TRANSPORTATION, AND MATERIALS

To prepare remedial cost estimates, assumptions were made in regards to the amount of excavation that could be feasibly accomplished per day, the amount of backfill that could be feasibly accomplished per day, no expansion of soil during excavation, the increased cubic yardage of soil needed for backfill, and the amount of material that could be transported to and from the Site per day. It was assumed that excavation could proceed at a rate of 250 cubic yards per day, hydraulic dredge could proceed at a rate of 250 cubic yards per day (does not include dewatering), backfill excavations could proceed at a rate of 400 cubic yards per day assuming that two dozers were operating 10-hour days, backfill would require 1.4 times the volume of the excavation to be filled. When transporting waste from the Site, it was assumed that each load would carry 15 cubic yards (~20 tons) of excavated material at a total cost of each load being $1,325 (this includes transportation, liners, cost of sediment/soil disposal, fuel surcharge and environmental fees). When transporting backfill and clay to the Site, it was assumed that each load would carry 15 and 12 cubic yards per load (~20 ton), at the cost of $240 and $140 per load, respectively. For the remedial actions that require an armored cap, it was assumed that the excavation would be backfilled 75 percent and an armored cap material would complete the final 25 percent of the excavation, cost estimates for these remedial actions reflect this assumption.

6.1.4 SAMPLE COLLECTION AND ANALYSIS

To classify waste and monitor progress of implemented remedial actions, sample collection and analysis is necessary. Waste characterization samples will be obtained for analysis from 10 percent of the trucks leaving the Site. These samples will be analyzed for an array of constituents including:

- PAHs
- PCBs
- total metals
- hexavalent chromium
- SVOCs
- VOCs

During implementation of remedial actions that involve excavation, it was assumed that confirmatory samples will be obtained from each of the following AOIs:

- Jefferson Canal – 15 samples
- Former Star Lake – 15 samples
- Star Lake Canal – 15 samples
- Molasses Bayou Waterway – 15 samples
- Jefferson Canal Spoil Pile – 10 samples
- Gulf States Utility Canal – 10 samples
- Molasses Bayou Wetland – 10 samples

Samples will be analyzed for COCs that have an established PRG. For a full list of analytes see Tables 3-4A and 3-4B.

Molasses Bayou Wetland and Waterway AOIs have the alternative option of MNR. It is assumed that five samples per year will collected from the Waterway AOI and three samples per Thiessen polygon (21 total) will be collected from the Wetland AOI, all samples will be analyzed for the COCs that have an established PRG as referenced in Tables 3-4A and 3-4B.

Soil/sediment sample analysis was assumed to cost $350 per sample for waste characterization tests and $900 per sample for the PRG suite of analytes (PAHs, PCBs, total metals, hexavalent chromium, SVOCs, and VOCs). Full Data Validation will be completed and will include review of deliverables, batch and instrument level quality control (QC), calibration information, raw and supporting data, and 10 percent calculation of data present in the package. A final report will be produced to review all findings.

6.1.5 COST PRECISION

Equal quotes for equipment, materials, and labor rates were used to develop a cost estimate for each alternative. Although the cost estimates may not be fully precise or accurate, the accuracy and precision of the cost estimate had limited affect on the selection of the alternative. If a quote for equipment, material, or labor rate changes, the increase or decrease shall apply to each alternative. This allows for an effective comparison since the cost change was applied to each alternative.

6.1.6 OPERATION AND MAINTENANCE COSTS

When developing cost estimates for remedial actions, it is necessary to accrue operation and maintenance (O&M) costs. It was assumed that all remedial alternatives would be monitored for a 10-year timeframe, on a semiannual basis. Cost estimates associated with O&M include, but are not limited to, site inspections, remedial design maintenance, land survey, and AOI-specific annual and semiannual reports.

6.2 JEFFERSON CANAL

6.2.1 ALTERNATIVE 1 – NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.2.2 ALTERNATIVE 2 – CONTAINMENT AND 12-INCH REMOVAL/ DISPOSAL AND BACKFILL: PIPE CONTAINMENT

This alternative requires the installation of a three 48-inch reinforced concrete pipes that will be extended 700 feet off an already existing set of concrete pipes at the Site. Pipes are designed to maintain the required hydraulic capacity along the polygon associated with sample number JC-7 of the canal. The remaining polygons of interest within Jefferson Canal (JC-2, JC-13, JC-18, and JC-19) will be excavated to a depth of 12-inches beneath existing grade and materials shall be transported to a licensed off-Site disposal facility. Clean backfill will be placed into excavated polygons brought to original grade. Table 6-1 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and Potentially Responsible Parties (PRPs). Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.2.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND BACKFILL

This alternative requires a 12-inch excavation of all polygons of interest within Jefferson Canal (JC-2, JC-7, JC-13, JC-18, and JC-19). Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. Clean backfill will be placed into excavated polygons brought to original grade. Table 6-1 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.3 JEFFERSON CANAL SPOIL PILE

6.3.1 ALTERNATIVE 1 - NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.3.2 ALTERNATIVE 2A - CONTAINMENT: COMPOSITE CAP

This alternative utilizes a composite cap as the form of containment of COCs within the existing media. Cap composition and thickness must be designed to prevent infiltration of rainwater and erosion by surface runoff. Cap composition will consist of a 12-inch layer of clay, to inhibit infiltration, overlaid with a 12-inch layer of top soil to allow for vegetative stabilization, throughout the entire AOI. Table 6-2 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.3.3 ALTERNATIVE 2B – PARTIAL CONTAINMENT: COMPOSITE CAP

This alternative utilizes a composite cap as the form of containment of COCs within the existing media. Cap composition and thickness must be designed to prevent infiltration of rainwater and erosion by surface runoff. Cap composition will consist of a 12-inch layer of clay, to inhibit infiltration, overlaid with a 12-inch layer of top soil to allow for vegetative stabilization. A 25-foot boundary surrounding the existing pipelines will be established and cap placement will follow the contour of this boundary to eliminate disturbance of materials near the established pipelines. Table 6-2 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.3.4 ALTERNATIVE 3A – 12-INCH PARTIAL REMOVAL/DISPOSAL AND CONTAINMENT: COMPOSITE CAP

This alternative requires a 12-inch excavation of polygons of interest within Jefferson Canal Spoil Pile, excluding the pipeline servitude. A 25-foot boundary surrounding existing pipelines will be created and excavation will only occur outside of this established boundary. Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. A composite cap will be utilized as the form of containment of COCs within the existing media. Cap composition and thickness must be designed to prevent infiltration of rainwater and erosion by surface runoff. Cap composition will consist of a 12-inch layer of clay, to inhibit infiltration, overlaid with a 12-inch layer of top soil to allow for vegetative stabilization, throughout the entire Jefferson Canal Spoil Pile AOI. Table 6-2 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.3.5 ALTERNATIVE 3B – 12-INCH PARTIAL REMOVAL/ DISPOSAL AND PARTIAL CONTAINMENT: COMPOSITE CAP

This alternative requires a 12-inch excavation of polygons of interest within Jefferson Canal Spoil Pile, excluding the pipeline servitude. A 25-foot boundary surrounding existing pipelines will be created and excavation will only occur outside of this established boundary. Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. A composite cap will be utilized as the form of containment of COCs within the existing media. Cap composition and thickness must be designed to prevent infiltration of rainwater and erosion by surface runoff. Cap composition will consist of a 12-inch layer of clay, to inhibit infiltration, overlaid with a 12-inch layer of top soil to allow for vegetative stabilization, only over the excavated area of the Jefferson Canal Spoil Pile AOI. Table 6-2 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.4 FORMER STAR LAKE

6.4.1 ALTERNATIVE 1 – NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.4.2 ALTERNATIVE 2 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH IMPERMEABLE CAP

This alternative requires a 12-inch excavation of all polygons of interest within Former Star Lake AOI. Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. An impermeable cap (clay) will be utilized to form a barrier between the benthic invertebrates and COC-affected sediment and resist erosion from a partially inundated drainage canal. The hydraulic capacity or the soil/water topography of the canal will not be modified by the cap design. Table 6-3 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.4.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND BACKFILL

This alternative requires a 12-inch excavation of all polygons of interest within Former Star Lake (SL-6, SL-7, SL-9, SL-10). Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. Clean backfill will be placed into excavated polygons and brought to original grade. Table 6-3 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by EPA and the PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.5 STAR LAKE CANAL

6.5.1 ALTERNATIVE 1 – NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.5.2 ALTERNATIVE 2 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH IMPERMEABLE CAP

This alternative requires a 12-inch excavation of all polygons of interest within Former Star Lake AOI. Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. An armored cap will be utilized to form a barrier between the benthic invertebrates and COC-affected sediment and resist erosion from a partially inundated drainage canal. The hydraulic capacity or the soil/water topography of the canal will not be modified by the cap design. Table 6-4 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.5.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH ARMORED CAP

This alternative requires a 12-inch excavation of all polygons of interest within Star Lake Canal (SLC-11 and SLC-6). Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. Excavation will be partially backfilled with clay and overlaid with an armored cap that will be utilized to form a barrier between the benthic invertebrates and COC-affected sediment and resist erosion from a partially inundated drainage canal. The hydraulic capacity or the soil/water topography of the canal will not be modified by the cap design. Table 6-4 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by EPA and the PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.6 GULF STATES UTILITY CANAL

6.6.1 ALTERNATIVE 1 – NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.6.2 ALTERNATIVE 2 – CONTAINMENT – WITHOUT EXCAVATION: 12-INCH COMPOSITE CAP

This alternative utilizes a composite cap as the form of containment of COCs within the polygon associated with sample number GSUC-7. Cap composition and thickness must be designed to reduce erosion of the soft canal bottom, and provide a new benthic habitat. Cap composition will consist of a 12-inch layer of clay, to inhibit infiltration and reduce erosion. Table 6-5 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.6.3 ALTERNATIVE 3 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH ARMORED CAP

This alternative requires a 12-inch excavation of the polygon associated with sample number GSUC-7. Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. Excavation will be partially backfilled with clay and overlaid with an armored cap that will be utilized to form a barrier between the benthic invertebrates and COC-affected sediment and resist erosion from a partially inundated drainage canal. The hydraulic capacity or the soil/water topography of the canal will not be modified by the cap design. Table 6-5 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.6.4 ALTERNATIVE 4 – 12-INCH REMOVAL AND DISPOSAL

This alternative requires a 12-inch excavation of the polygon associated with sample number GSUC-7. Material will be excavated with heavy equipment and transported to a licensed off-Site disposal facility. Excavation will not be backfilled and the hydraulic capacity or the soil/water topography of the canal will be modified by this design. Table 6-5 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Treatment and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Treatment and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.7 MOLASSES BAYOU (WATERWAY POLYGONS)

6.7.1 ALTERNATIVE 1 – NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.7.2 ALTERNATIVE 2 – MONITORED NATURAL RECOVERY

This alternative utilizes naturally driven degradation and dispersion processes within the polygons associated with sample numbers MB-10, MB-14, MB-18/MB-18R, MB-21, MB-24, MB-49, MB-52, MB-60, and MB-61. The MNR alternative lowers the risk of interaction between benthic invertebrates and the sediment very gradually. Overall protection of the environment depends upon the rate of naturally driven degradation and dispersion processes. Table 6-6 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.7.3 ALTERNATIVE 3 - 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH ARMORED CAP

This alternative requires a 12-inch excavation of the polygons associated with sample numbers MB-10, MB-14, MB-18/MB-18R, MB-21, MB-24, MB-49, MB-52, MB-60, and MB-61. Material will be excavated with hydraulic dredge equipment, staged in an area to be de-watered (by filter press or Geo-Tubes) and transported to a licensed off-Site disposal facility. Excavation will be partially backfilled with clay and overlaid with an armored cap that will be utilized to form a barrier between the benthic invertebrates and COC-affected sediment and resist erosion from soft bottom bayou. The hydraulic capacity or the soil/water topography of the canal will not be modified by the cap design. Table 6-6 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.8 MOLASSES BAYOU (WETLAND POLYGONS)

6.8.1 ALTERNATIVE 1 – NO ACTION

A cost estimate is not needed since there is no remedial action taken for the No Action alternative.

6.8.2 ALTERNATIVE 2 – MONITORED NATURAL RECOVERY (MNR)

This alternative utilizes naturally driven degradation and dispersion processes within the polygons associated with sample numbers MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, and MB-63. The MNR alternative lowers the risk of interaction between benthic invertebrates and the sediment very gradually. Overall protection of the environment depends upon the rate of naturally driven degradation and dispersion processes. Table 6-7 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.8.3 ALTERNATIVE 3 – CONTAINMENT – WITHOUT EXCAVATION: 12-INCH COMPOSITE CAP

This alternative utilizes a composite cap as the form of containment of COCs within the polygons associated with sample numbers MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, and MB-63. Cap composition and thickness must be designed to reduce erosion of the soft canal bottom, and provide a new benthic habitat. Cap composition will consist of a 12-inch layer of clay, to inhibit infiltration and reduce erosion of the soft bottom bayou. Table 6-7 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.8.4 ALTERNATIVE 4 – 12-INCH REMOVAL/DISPOSAL AND CONTAINMENT: 12-INCH ARMORED CAP

This alternative requires a 12-inch excavation of the polygons associated with sample numbers MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, and MB-63. Material will be excavated with hydraulic dredge equipment, staged in an area to be de-watered (by filter press or Geo-Tubes) and transported to a licensed off-Site disposal facility. Excavation will be partially backfilled with clay and overlaid with an armored cap that will be utilized to form a barrier between the benthic invertebrates and COC-affected sediment and resist erosion from soft bottom bayou. Table 6-7 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

6.8.5 ALTERNATIVE 5 – 12-INCH REMOVAL AND DISPOSAL

This alternative requires a 12-inch excavation of the polygons associated with sample numbers MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, and MB-63. Material will be excavated with hydraulic dredge equipment, staged in an area to be de-watered (by filter press or Geo-Tubes) and transported to a licensed off-Site disposal facility. Excavation will not be backfilled and the hydraulic capacity or the soil/water topography of the canal will be modified by this design. Table 6-7 displays the cost summary to implement this alternative. The costs are separated into three categories: Base Implementation, Remediation and Disposal, and Present-Worth O&M Costs. Base Implementation Costs are defined as, but not limited to, equipment and personnel mobilization to and from the Site, pre-remediation Site work, facilities, and Site characterization sampling and analysis. Remediation and Disposal Costs are defined as, but not limited to, equipment (excavator, loader, trucks, etc.), operators (includes lodging, transportation, per diem and wages), materials (cap, backfill, pipe, etc.), and disposal costs of the off-Site disposal facility. All material, equipment, and disposal price calculations were based from verbal or written quotes obtained from licensed, regional vendors approved by the EPA and PRPs. Present Worth O&M Costs are defined as, but are not limited to, engineered monitoring equipment (including installation), annual maintenance, and monitoring. Maintenance and monitoring events are scheduled annually and semiannually for a 10-year time frame. Monitoring events include sample collection and analysis to determine status and progress of remedial action implementation and a thorough AOI site inspection. All sample analysis costs were calculated from quotes obtained from a qualified laboratory.

7.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section presents the comparative analysis of the remedial alternatives for each of the seven AOIs. The objective of the comparative analysis is to identify the advantages and disadvantages of each remedial alternative relative to one another within an AOI, and provide key information for use in determination of the selected remedy. The nine criteria discussed in detail in Section 5.0 (overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, reduction of toxicity, mobility, and volume, short-term effectiveness, implementability, cost (Section 6.0), state acceptance, and community acceptance) are used to compare the remedial alternatives for each AOI in this section. Tables 7-1 through 7-7 document the comparative analysis of the remedial alternatives based on the nine criteria for Jefferson Canal AOI, Jefferson Canal Spoil Pile AOI, Former Star Lake AOI, Star Lake Canal AOI, Gulf States Utility Canal AOI, Molasses Bayou Waterway AOI, and Molasses Bayou Wetland AOI, respectively.

A criteria and numerical scoring system for the evaluation of remedial alternatives is used in Tables 7-1 through 7-7. The two threshold criteria (overall protection of human health and the environment and compliance with ARARs) are scored with a letter N - does not satisfy the criteria or an S - satisfies the criteria. The balancing criteria (long-term effectiveness and permanence, reduction of toxicity, mobility, and volume, short-term effectiveness, implementability, and cost) are scored by a numerical ranking system to compare these specific criteria for each remedial alternative with one another for each AOI. The ranking system scales the balancing criteria on 1-low, 2-low to moderate, 3-moderate, 4-moderate to high, and 5-high. Modifying criteria (state and community acceptance) are evaluated subsequent to submittal of the FS Report.

7.1 JEFFERSON CANAL

The comparative analysis for Jefferson Canal is shown on Table 7-1. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.
- Alternative 2, containment and 12-inch removal/disposal and backfill, meets the threshold criteria.
- Alternative 3, 12-inch removal/disposal and backfill, meets the threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2, 12-inch removal/disposal and containment alternative, meets the balancing criteria.
- Alternative 3, 12-inch removal/disposal and backfill, meets the balancing criteria.
- Cost for Alternative 3 is less than Alternative 2.

Alternative 3 appears to be the best choice based on scores from the balancing criteria.

7.2 JEFFERSON CANAL SPOIL PILE

The comparative analysis for Jefferson Canal Spoil Pile is shown on Table 7-2. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.
- Alternative 2a, containment without excavation, meets the threshold criteria.
- Alternative 2b, partial containment without excavation, does not meet the threshold criteria.
- Alternative 3a, 12-inch partial removal/disposal and containment: composite cap, meets the threshold criteria.
- Alternative 3b, 12-inch partial removal/disposal and partial containment: composite cap, does not meet the threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2a, containment without excavation, meets the balancing criteria.
- Alternative 2b, partial containment without excavation, meets the balancing criteria for only 70 percent of soil within the AOI.
- Alternative 3a, 12-inch partial removal/disposal and containment: composite cap, meets the balancing criteria.
- Alternative 3b, 12-inch partial removal/disposal and partial containment: composite cap, meets the balancing criteria for only 70 percent of soil within the AOI.

- The costs for Alternatives 2a and 2b are less than the costs for Alternatives 3a and 3b.

Alternative 2a appears to be the best choice based on scores from the balancing criteria.

7.3 FORMER STAR LAKE

The comparative analysis for Former Star Lake is shown on Table 7-3. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.
- Alternative 2, 12-inch removal/disposal and containment: 12-inch impermeable cap, meets the threshold criteria.
- Alternative 3, 12-inch removal/disposal and backfill: 12-inch soil cap, meets threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2, 12-inch removal/disposal and containment: 12-inch impermeable cap, meets the balancing criteria.
- Alternative 3, 12-inch removal/disposal and backfill: 12-inch soil cap, meets balancing criteria.
- Cost for Alternative 2 is less than cost for Alternative 3.

Alternative 2 appears to be the best choice based on scores from the balancing criteria.

7.4 STAR LAKE CANAL

The comparative analysis for Star Lake Canal is shown on Table 7-4. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.

- Alternative 2, 12-inch removal/disposal and containment: 12-inch impermeable cap, meets the threshold criteria.
- Alternative 3, 12-inch removal/disposal and containment: 12-inch armored cap, meets the threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2, 12-inch removal/disposal and containment: 12-inch impermeable cap, meets the balancing criteria.
- Alternative 3, 12-inch removal/disposal and containment: 12-inch armored cap, meets the balancing criteria.
- Cost for Alternative 2 is less than cost for Alternative 3.

Alternative 2 appears to be the best choice based on scores from the balancing criteria.

7.5 GULF STATES UTILITY CANAL

The comparative analysis for Gulf States Utility Canal is shown on Table 7-5. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.
- Alternative 2, containment without excavation: 12-inch composite cap, meets the threshold criteria.
- Alternative 3, 12-inch removal/disposal and containment: 12-inch armored cap, meets the threshold criteria.
- Alternative 4, 12-inch removal/disposal, meets the threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2, containment without excavation: 12-inch composite cap, meets the balancing criteria.
- Alternative 3, 12-inch removal/disposal and containment: 12-inch armored cap, meets the balancing criteria.

- Alternative 4, 12-inch removal/disposal, meets the balancing criteria.
- Cost for Alternative 4 is less than Alternatives 2 and 3.

Alternative 4 appears to be the best choice based on scores from the balancing criteria.

7.6 MOLASSES BAYOU WATERWAY

The comparative analysis for Molasses Bayou Waterway is shown on Table 7-6. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.
- Alternative 2, Monitored Natural Recovery, meets the threshold criteria.
- Alternative 3, 12-inch removal/disposal and containment: armored cap, meets the threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2, Monitored Natural Recovery, meets the balancing criteria.
- Alternative 3, 12-inch removal/disposal and containment: 12-inch armored cap, meets the balancing criteria.
- Cost for Alternative 2 is less than Alternative 3.

Alternative 2 appears to be the best choice based on scores from the balancing criteria.

7.7 MOLASSES BAYOU WETLAND

The comparative analysis for Molasses Bayou Wetland is shown on Table 7-7. The comparison shows:

Threshold Criteria

- Alternative 1, No Action, does not meet the threshold criteria.
- Alternative 2, Monitored Natural Recovery, does meet the threshold criteria.

- Alternative 3, containment without excavation: 12-inch composite cap, meets the threshold criteria.
- Alternative 4, 12-inch removal/disposal and containment: 12-inch armored cap, meets the threshold criteria.
- Alternative 5, 12-inch removal/disposal, meets the threshold criteria.

Balancing Criteria

- Alternative 1, No Action, meets the balancing criteria.
- Alternative 2, Monitored Natural Recovery, meets the balancing criteria.
- Alternative 3, containment without excavation: 12-inch composite cap, meets the balancing criteria.
- Alternative 4, 12-inch removal/disposal and containment: 12-inch armored cap, meets the balancing criteria.
- Alternative 5, 12-inch removal/disposal, meets the balancing criteria.
- Alternative 2 is the least expensive of Alternatives 2 through 5.

Alternative 2 appears to be the best choice based on scores from the balancing criteria.

7.8 SUMMARY OF PREFERRED ALTERNATIVES

The preferred alternatives were selected based on the nine criteria. The following are preferred:

- Jefferson Canal – Alternative 3: 12-inch Removal/Disposal and Backfill: $783,000
- Jefferson Canal Spoil Pile – Alternative 2a: Containment without Excavation (Composite Cap): $1,751,000
- Former Star Lake – Alternative 2: 12-inch Removal/Disposal and 12-inch Impermeable Cap: $2,741,000
- Star Lake Canal – Alternative 2: 12-inch Removal/Disposal and 12-inch Impermeable Cap: $2,846,000
- Gulf States Utility Canal – Alternative 4: 12-inch Removal/Disposal: $544,000
- Molasses Bayou Waterway – Alternative 2: Monitored Natural Recovery: $564,000
- Molasses Bayou Wetlands – Alternative 2: Monitored Natural Recovery: $1,487,000

The estimated cost of these alternatives is $10,716,000.

8.0 REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. Toxicological Profile for Chromium. U.S. Dept. Health & Human Services, TP-92/08.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. Toxicological Profile for Antimony. U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). September 2008. Public Health Statement for Cadmium. U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Toxicological Profile for Chromium (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Toxicological Profile for Manganese (Update). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile for Copper (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Lead (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 1999 Toxicological Profile for Mercury (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2003. Toxicological Profile for Selenium (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological Profile for Silver (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological Profile for Zinc (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2002. Toxicological Profile for DDE, DDT, and DDD (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2002. Toxicological Profile for Dieldrin (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological Profile for Endosulfan II (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2010. Toxicological Profile for Ethylbenzene (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 1996. Toxicological Profile for Carbon Disulfide (Draft). U.S. Public Health Service, Washington, D.C.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Pentachlorophenol (Draft). U.S. Public Health Service, Washington, D.C.

Eisler, R. 1986. Chromium Hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildlife Service Biol. Rep. 85(1.6).

Offiong, S.A. and S.M. Abed. 1980. Fertility, hatchability and malformations in guinea fowl embryos as affected by dietary manganese. Brit. Poult. Sci. 21:371-375.

Oliver, M.A., and R. Webster. 2007. Prediction and Interpolation. In Geostatistics for Environmental Scientists. Second Edition. Pp.37-40. West Sussex: John Wiley and Sons, Ltd.

OMB (Office of Management and Budget). 2011. Memorandum for the Heads of Departments and Agencies: 2012 Discount Rates for Circular No. A-94. Revised December 2011.

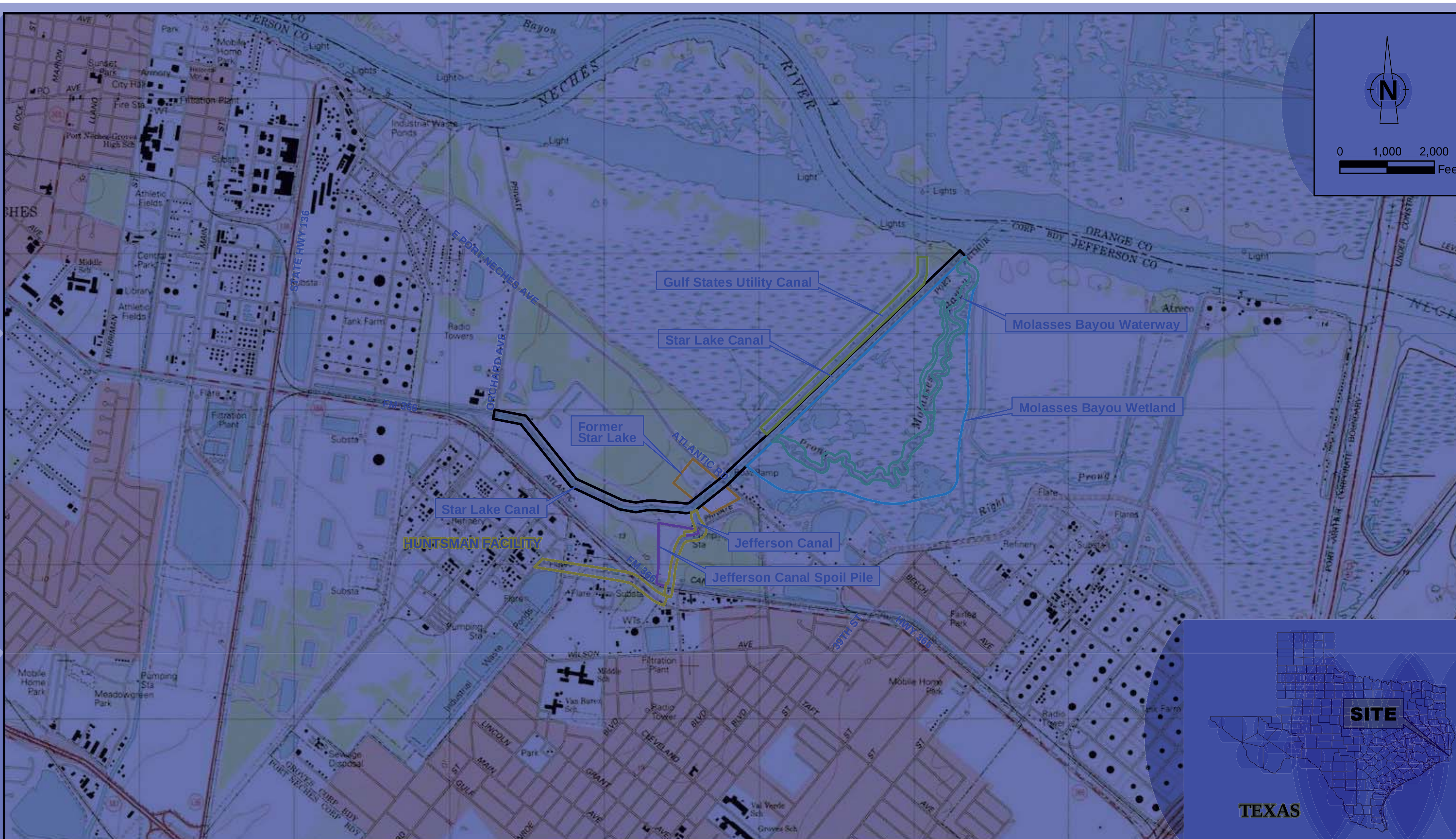
Schafer, E.W., Jr., W.A. Bowles and J. Hurlbut. 1983. The acute oral toxicity, repellency, and hazard potential of 998 chemicals to one or more species of wild and domestic birds. Arch. Environ. Contam. Toxicol. 12:355-382.

Texas Commission of Environmental Quality (TCEQ). 2005. Position Paper on Common Issues Encountered During the Review of Ecological Risk Assessments. Remediation Division. September.

U.S. Environmental Protection Agency (USEPA). 1988. Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. EPA/540/G-89/004. OSWER Directive No. 9355.3-01. October 1988.

USEPA. 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002/OSWER 9344.0-85. July.

FIGURES

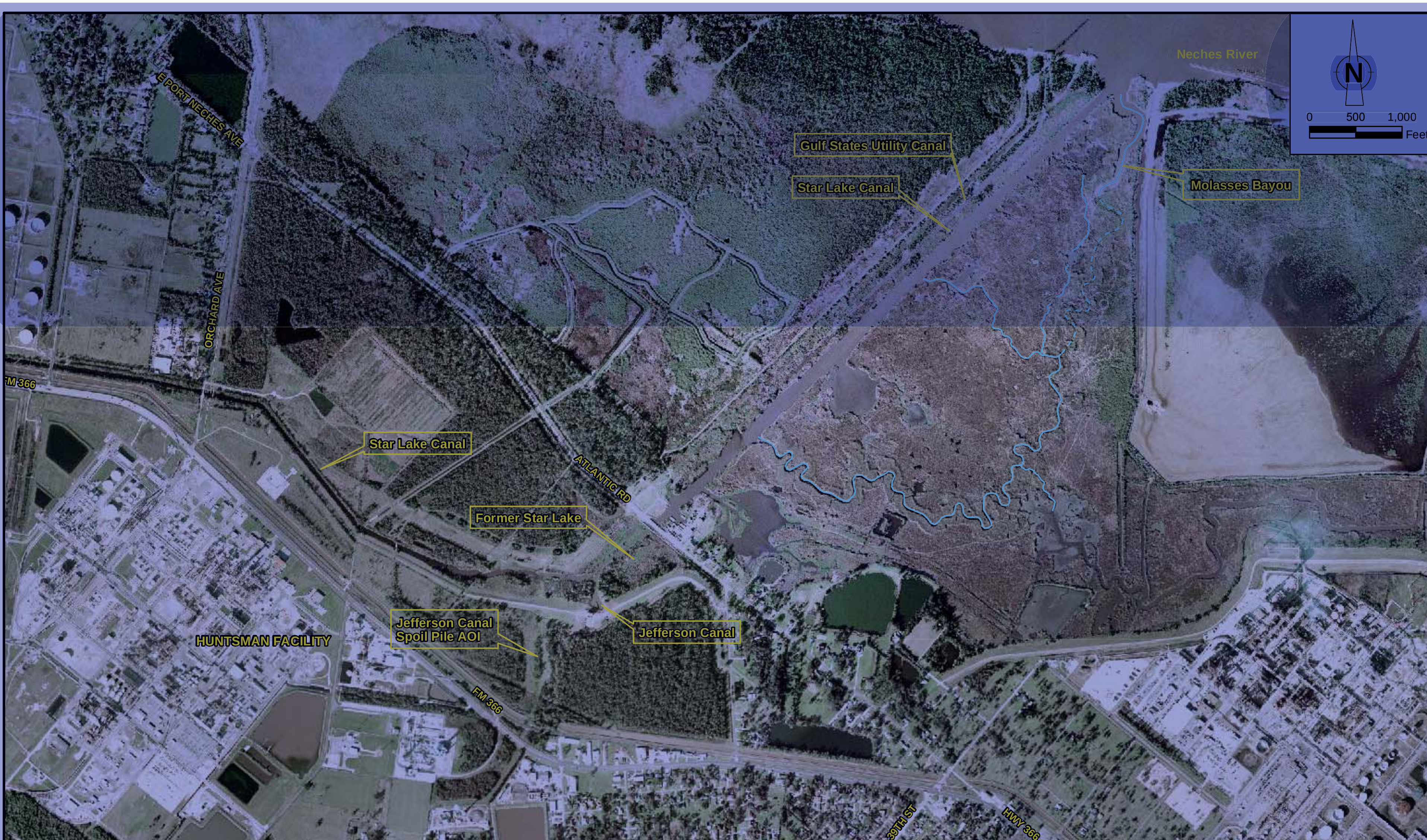


RE: USGS 1996 7.5 Minute Topographic Maps.

Figure 1-1
VICINITY MAP
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

CRA

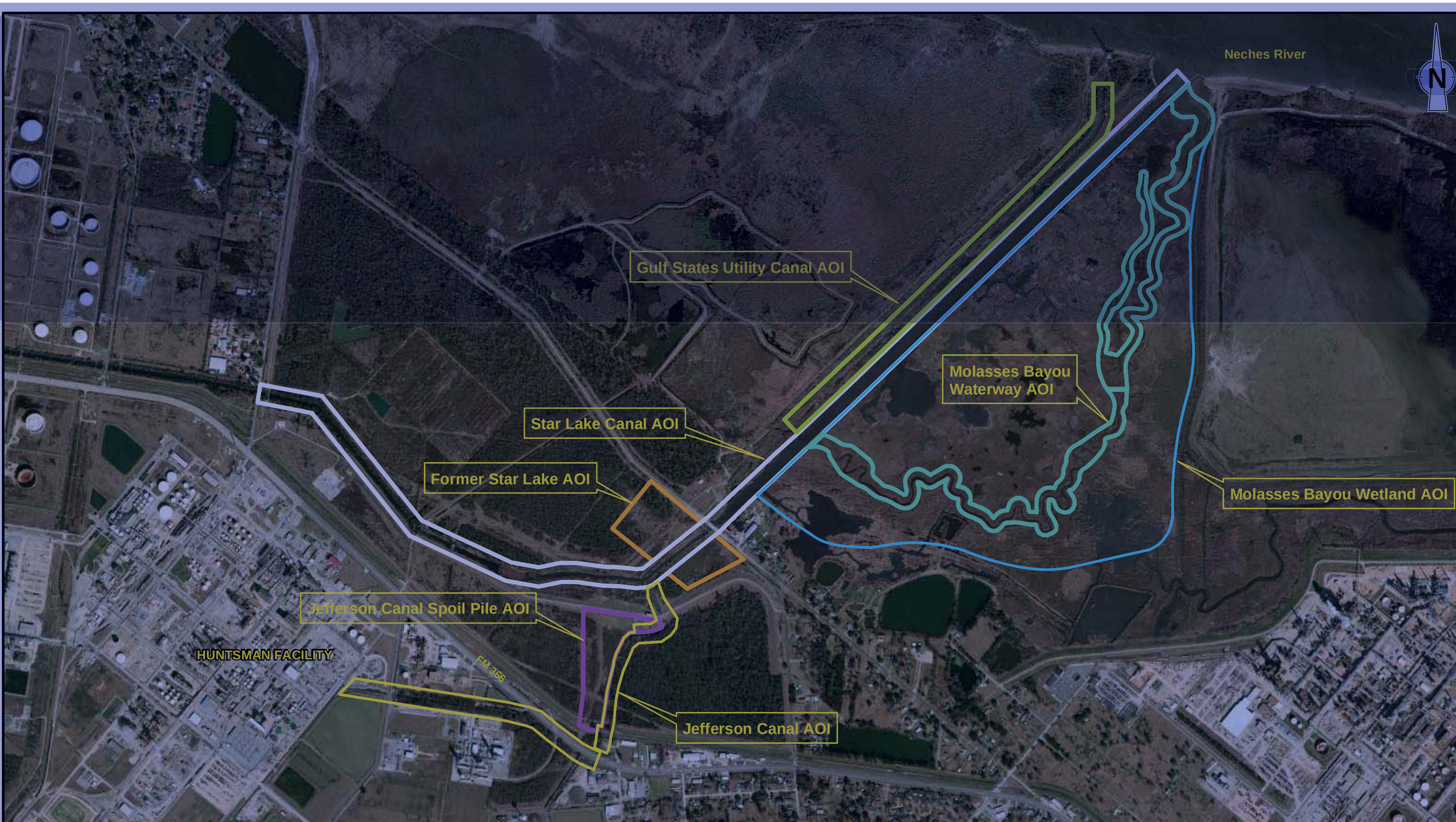
27545-00(019)PR-BR002 MAR 29/2012



RE: USGS 2007 Aerial Photograph "High Resolution State Orthoimagery for Southeast Texas."

Figure 1-2
AERIAL PHOTOGRAPH
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

27545-00(019)PR-BR003 Apr 13/2012



RE: 2010 Aerial by Microsoft Corp and its data suppliers.

0 500 1,000
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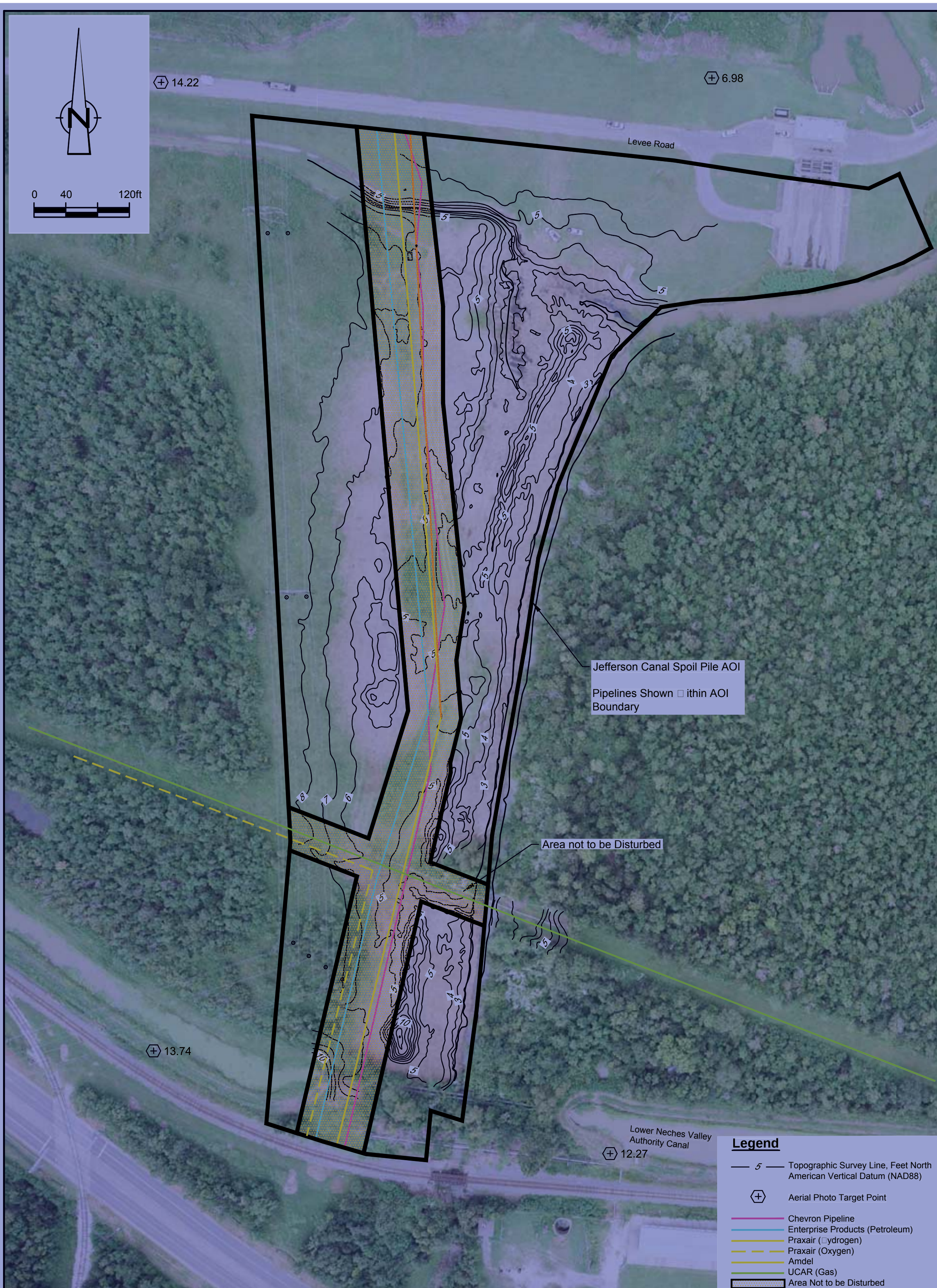
Figure 1-3
SITE MAP - AREAS OF INVESTIGATION
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR004 MAR 29/2012

RE: Aerial photograph by Gulf Coast Aerial Mapping dated August 31, 2009.

Figure 1-4
JEFFERSON CANAL SPOIL PILE AOI TOPOGRAPHIC SURVEY MAP
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

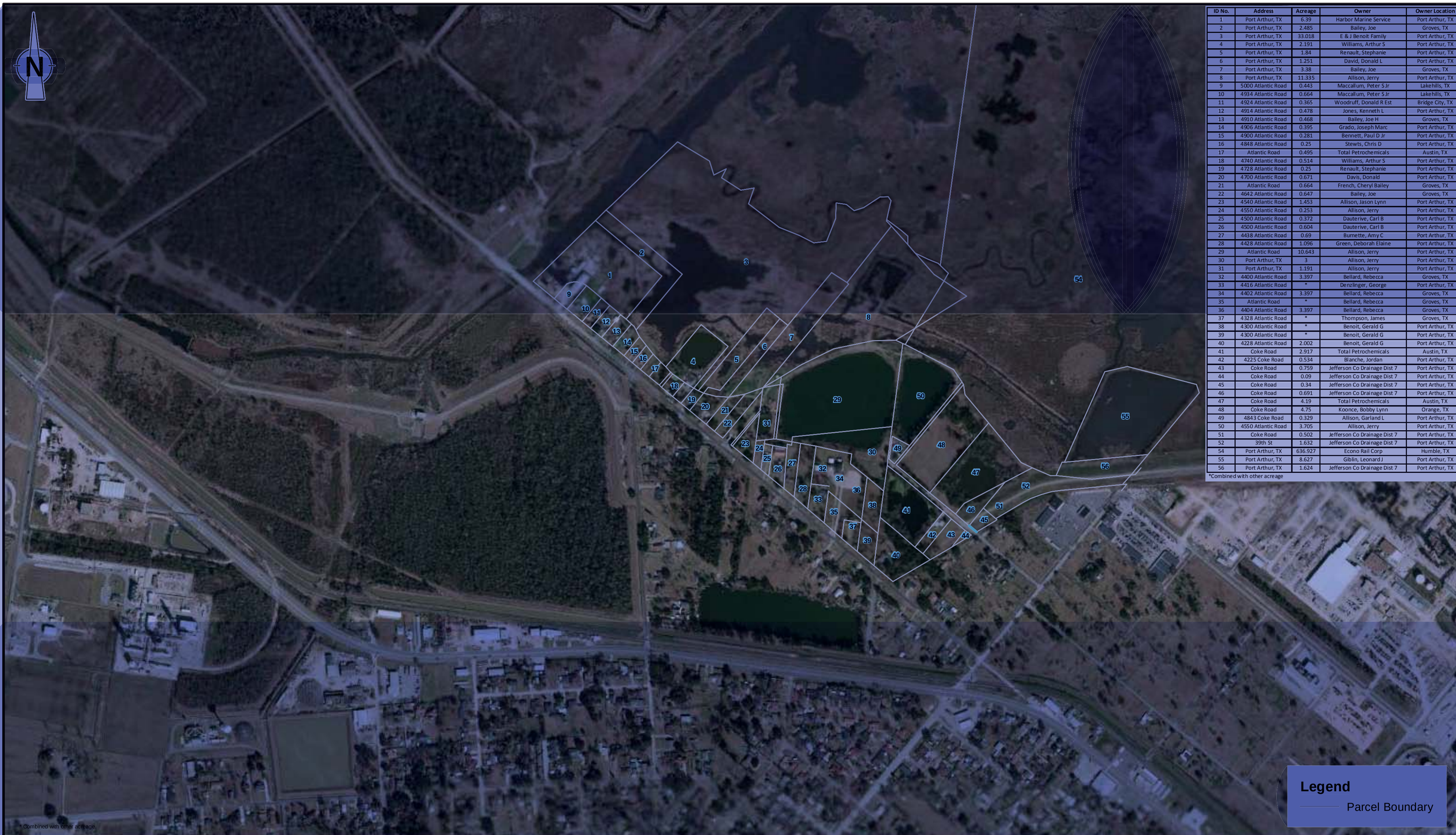
027545-00(019)GN-BR004 MAR 30/2012



RE: Aerial photograph by Gulf Coast Aerial Mapping dated August 31, 2009.

Figure 1-5
PIPELINES IN T□E VICINITY OF JEFFERSON CANAL SPOIL PILE AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

027545-00(019)GN-BR005 APR 2/2012



ID No.	Address	Acreage	Owner	Owner Location
1	Port Arthur, TX	6.39	Harbor Marine Service	Port Arthur, TX
2	Port Arthur, TX	2.485	Bailey, Joe	Groves, TX
3	Port Arthur, TX	33.018	E & J Benoit Family	Port Arthur, TX
4	Port Arthur, TX	2.191	Williams, Arthur S	Port Arthur, TX
5	Port Arthur, TX	1.84	Renault, Stephanie	Port Arthur, TX
6	Port Arthur, TX	1.251	David, Donald L	Port Arthur, TX
7	Port Arthur, TX	3.38	Bailey, Joe	Groves, TX
8	Port Arthur, TX	11.335	Allison, Jerry	Port Arthur, TX
9	5000 Atlantic Road	0.443	Maccallum, Peter S Jr	Lakehills, TX
10	4934 Atlantic Road	0.664	Maccallum, Peter S Jr	Lakehills, TX
11	4924 Atlantic Road	0.365	Woodruff, Donald R Est	Bridge City, TX
12	4914 Atlantic Road	0.478	Jones, Kenneth L	Port Arthur, TX
13	4910 Atlantic Road	0.468	Bailey, Joe H	Groves, TX
14	4906 Atlantic Road	0.395	Grado, Joseph Marc	Port Arthur, TX
15	4900 Atlantic Road	0.281	Bennett, Paul D Jr	Port Arthur, TX
16	4848 Atlantic Road	0.25	Stewts, Chris D	Port Arthur, TX
17	Atlantic Road	0.495	Total Petrochemicals	Austin, TX
18	4740 Atlantic Road	0.514	Williams, Arthur S	Port Arthur, TX
19	4728 Atlantic Road	0.25	Renault, Stephanie	Port Arthur, TX
20	4700 Atlantic Road	0.671	Davis, Donald	Port Arthur, TX
21	Atlantic Road	0.664	French, Cheryl Bailey	Groves, TX
22	4642 Atlantic Road	0.647	Bailey, Joe	Groves, TX
23	4540 Atlantic Road	1.453	Allison, Jason Lynn	Port Arthur, TX
24	4550 Atlantic Road	0.253	Allison, Jerry	Port Arthur, TX
25	4500 Atlantic Road	0.372	Dauterive, Carl B	Port Arthur, TX
26	4500 Atlantic Road	0.604	Dauterive, Carl B	Port Arthur, TX
27	4438 Atlantic Road	0.69	Burnette, Amy C	Port Arthur, TX
28	4428 Atlantic Road	1.096	Green, Deborah Elaine	Port Arthur, TX
29	Atlantic Road	10.643	Allison, Jerry	Port Arthur, TX
30	Port Arthur, TX	3	Allison, Jerry	Port Arthur, TX
31	Port Arthur, TX	1.191	Allison, Jerry	Port Arthur, TX
32	4400 Atlantic Road	3.397	Bellard, Rebecca	Groves, TX
33	4416 Atlantic Road	*	Denzlinger, George	Port Arthur, TX
34	4402 Atlantic Road	3.397	Bellard, Rebecca	Groves, TX
35	Atlantic Road	*	Bellard, Rebecca	Groves, TX
36	4404 Atlantic Road	3.397	Bellard, Rebecca	Groves, TX
37	4328 Atlantic Road	*	Thompson, James	Groves, TX
38	4300 Atlantic Road	*	Benoit, Gerald G	Port Arthur, TX
39	4300 Atlantic Road	*	Benoit, Gerald G	Port Arthur, TX
40	4228 Atlantic Road	2.002	Benoit, Gerald G	Port Arthur, TX
41	Coke Road	2.917	Total Petrochemicals	Austin, TX
42	4225 Coke Road	0.534	Blanche, Jordan	Port Arthur, TX
43	Coke Road	0.759	Jefferson Co Drainage Dist 7	Port Arthur, TX
44	Coke Road	0.09	Jefferson Co Drainage Dist 7	Port Arthur, TX
45	Coke Road	0.34	Jefferson Co Drainage Dist 7	Port Arthur, TX
46	Coke Road	0.691	Jefferson Co Drainage Dist 7	Port Arthur, TX
47	Coke Road	4.19	Total Petrochemicals	Austin, TX
48	Coke Road	4.75	Koonce, Bobby Lynn	Orange, TX
49	4843 Coke Road	0.329	Allison, Garland L	Port Arthur, TX
50	4550 Atlantic Road	3.705	Allison, Jerry	Port Arthur, TX
51	Coke Road	0.502	Jefferson Co Drainage Dist 7	Port Arthur, TX
52	39th St	1.632	Jefferson Co Drainage Dist 7	Port Arthur, TX
54	Port Arthur, TX	636.927	Econo Rail Corp	Humble, TX
55	Port Arthur, TX	8.627	Giblin, Leonard J	Port Arthur, TX
56	Port Arthur, TX	1.624	Jefferson Co Drainage Dist 7	Port Arthur, TX

*Combined with other acreage

RE: 2010 Aerial by Microsoft Corp and its data suppliers
Jefferson County Appraisal District Office Maps, Sheet 315D, B315, 326C.

Note: Property boundaries depicted are exactly as shown on
Jefferson County Appraisal District Office Maps.

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Figure 1-6
PROPERTY BOUNDARY MAP
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR011 Mar 29/2012

RE: USGS 2007 Aerial Photograph "High Resolution State Orthoimagery for Southeast Texas."

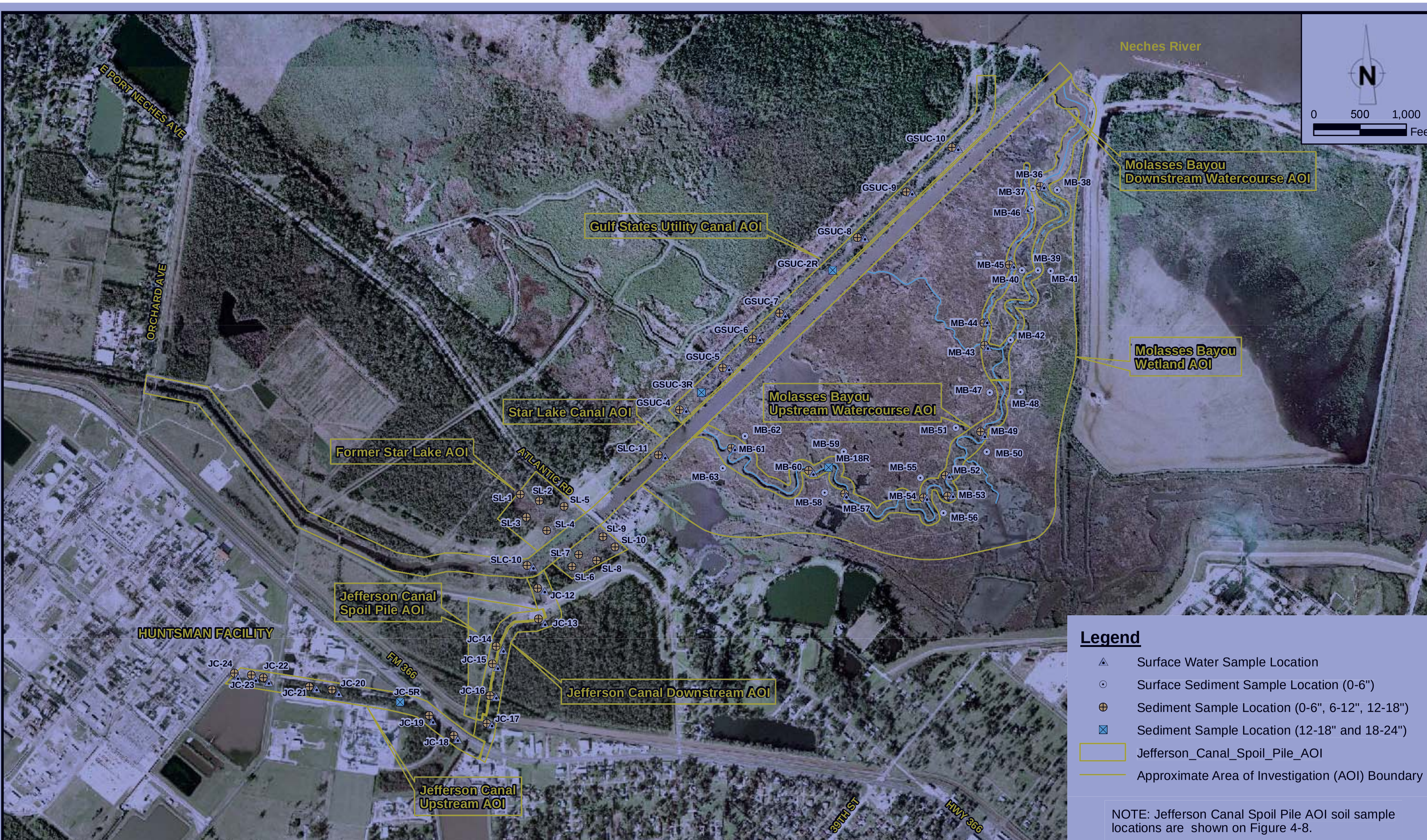
Figure 2-1

TIER 1 REMEDIAL INVESTIGATION SAMPLE LOCATIONS

STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS

Chevron Environmental Management Company, Bellaire, Texas

27545-00(019)PR-BR005 mar 29/2012



RE: USGS 2007 Aerial Photograph "High Resolution State Orthoimagery for Southeast Texas."

Figure 2-2
TIER 2 REMEDIAL INVESTIGATION SAMPLE LOCATIONS
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

27545-00(019)PR-BR0006 mar 29/2012

RE: Aerial photograph by Gulf Coast Aerial Mapping dated August 31, 2009.

Figure 2-3
TIER 1 AND TIER 2 REMEDIAL INVESTIGATION SOIL SAMPLE LOCATIONS - JEFFERSON CANAL SPOIL PILE AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

027545-00(019)GN-BR001 MAR 30/2012

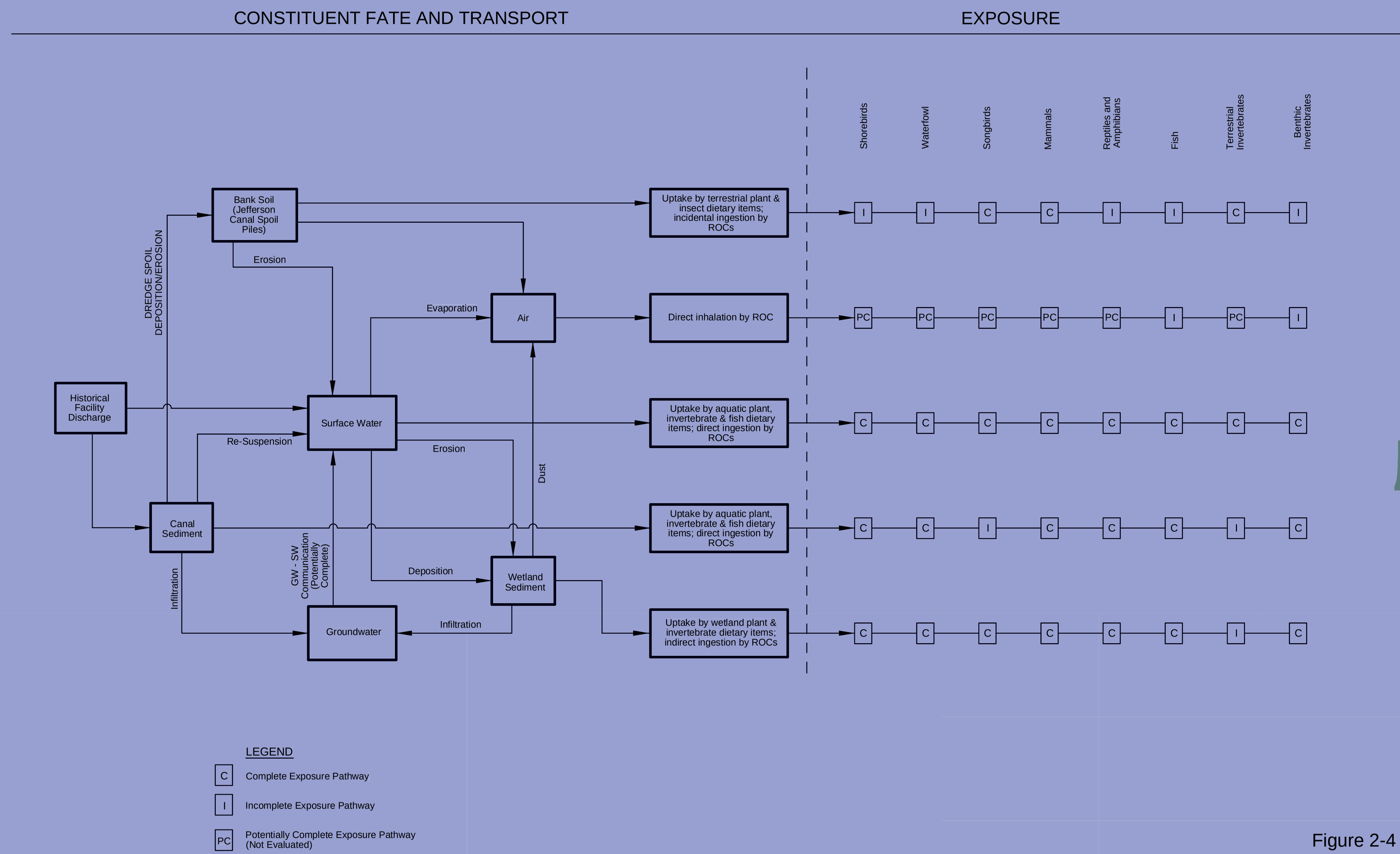
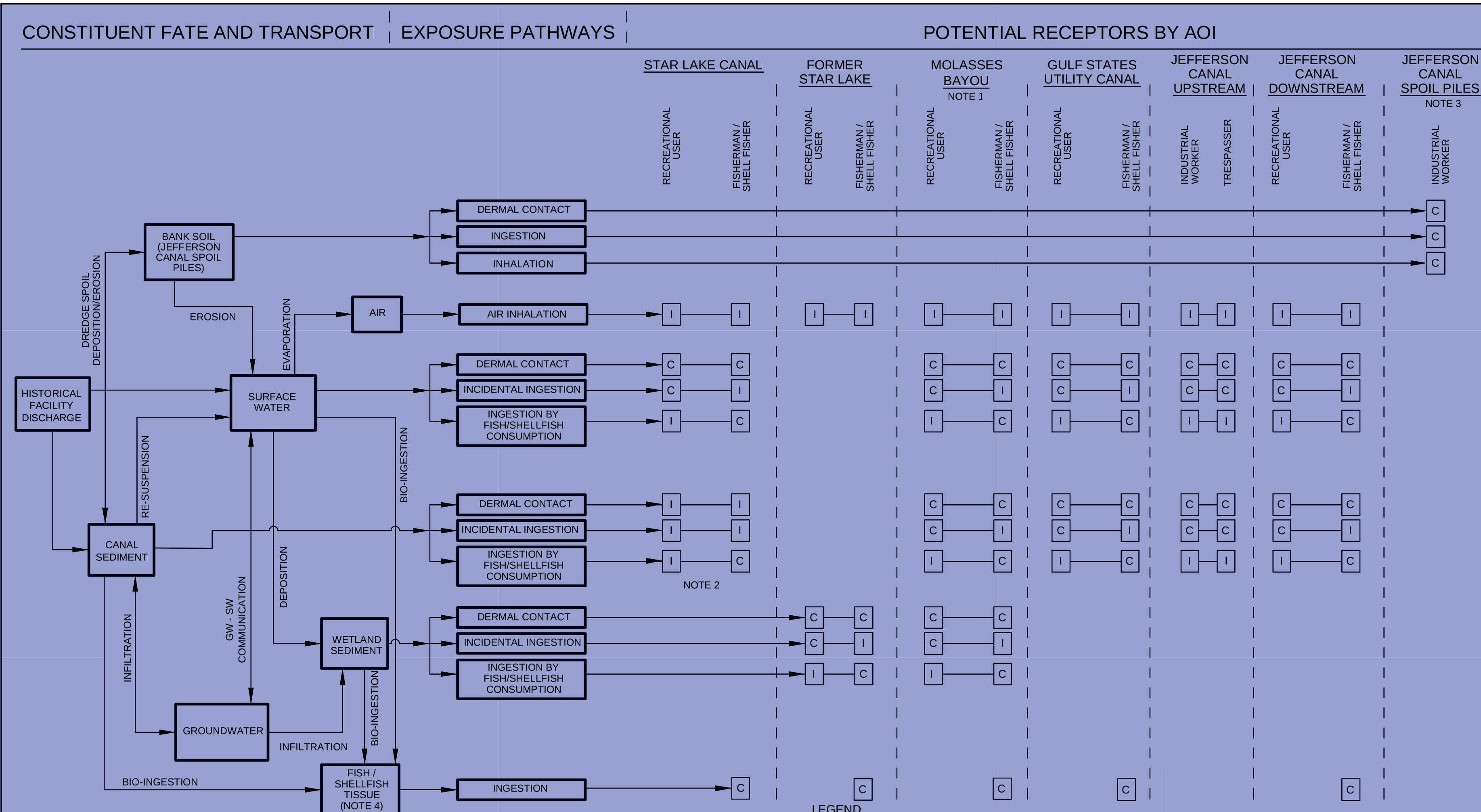


Figure 2-4
ECOLOGICAL CONCEPTUAL SITE MODEL
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

027545-00(019)GN-BR002 MAR 30/2012



C	COMPLETE EXPOSURE PATHWAY (EVALUATED QUANTITATIVELY)
I	INCOMPLETE OR INSIGNIFICANT EXPOSURE PATHWAY (NOT EVALUATED)

LEGEND

NOTES:
1) MOLASSES BAYOU INCLUDES THE MOLASSES BAYOU UPSTREAM WATERCOURSE, DOWNSTREAM WATERCOURSE, AND WETLAND AOIs.
2) INCOMPLETE DERMAL CONTACT AND INCIDENTAL INGESTION PATHWAY WAS EVALUATED FOR RECREATIONAL USERS DURING SITE SCREENING IN THE TIER 1 RI AND PERTINENT COCs WERE CARRIED FORWARD TO TIER 2 RI.
3) INDUSTRIAL SOIL PROTECTIVE OF INGESTION, DERMAL CONTACT, INHALATION, AND COMBINED INGESTION-DERMAL-INHALATION.
4) FISH TISSUE SAMPLE RESULTS WERE USED TO ADDRESS POTENTIAL HUMAN HEALTH IMPACTS FROM INGESTION OF FISH RATHER THAN USE OF PARTITION MODELING OF CONSTITUENTS FROM SURFACE WATER OR SEDIMENT TO FISH TISSUE.

Figure 2-5
HUMAN HEALTH CONCEPTUAL SITE MODEL
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

027545-00(019)GN-BR003 MAR 30/2012

Figure 2-6
MAGNITUDE OF PCL EXCEEDANCES
FOR ALL COPECs AND ALL RECEPTORS FOR SEDIMENT
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

RE: August 2009 Gulf Coast Aerial Mapping Photograph.
Data provided by Cardno Entrix, Houston, Texas.

27545-00(019)PR-BR007 MAR 29/2011

Figure 2-7
MAGNITUDE OF PCL EXCEEDANCES
FOR ALL COPECs AND ALL RECEPTORS FOR SOIL
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Bellaire, Texas

RE: August 2009 Gulf Coast Aerial Mapping Photograph.
Data provided by Cardno Entrix, Houston, Texas.

27545-00(019)PR-BR008 MAR 29/2011

RE: 2010 Aerial by Microsoft Corp and its data suppliers

0 400 800 Feet

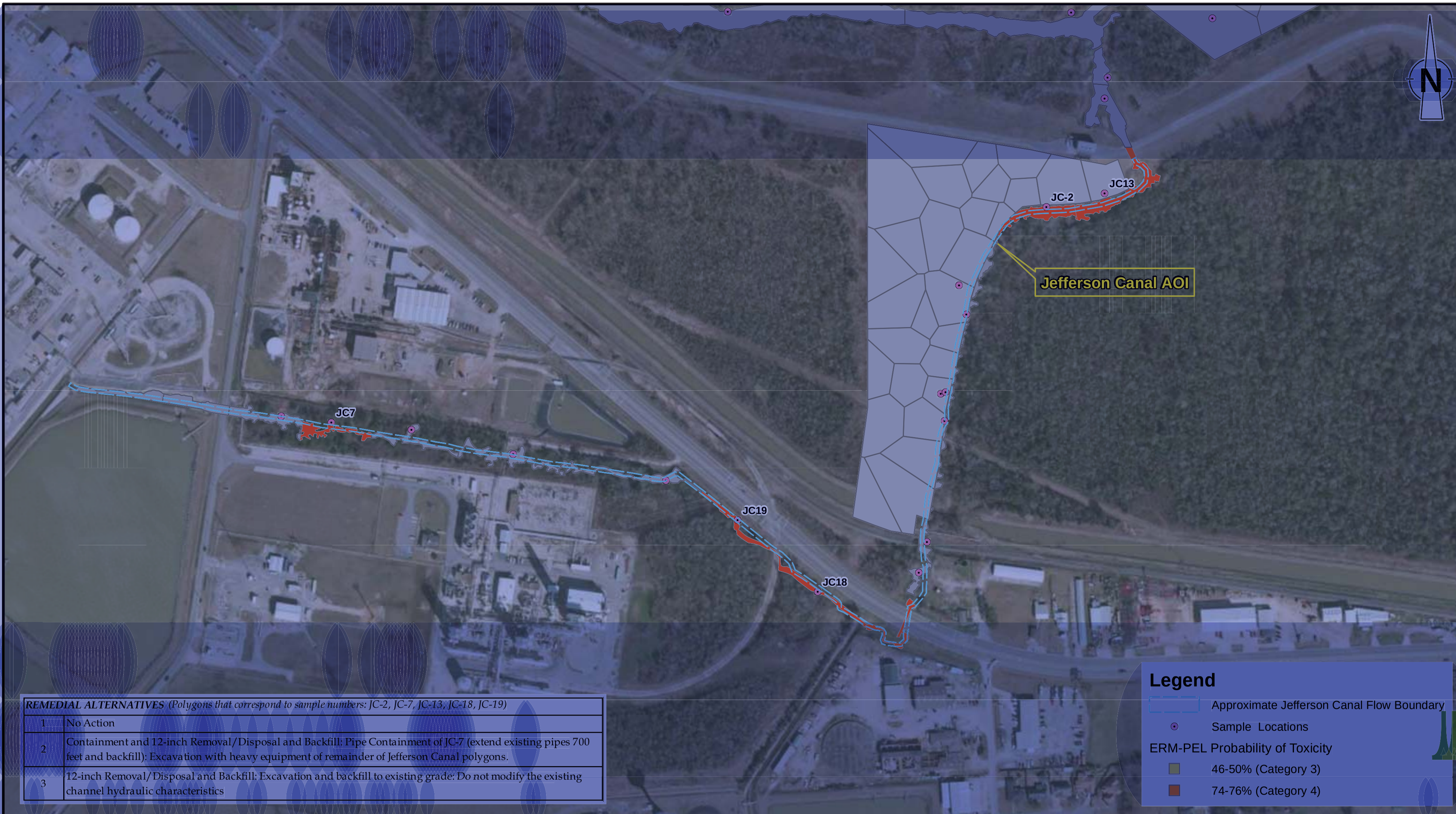
Figure 2-8
THIESSEN POLYGONS
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR009 Mar 30/2012

RE: 2010 Aerial by Microsoft Corp and its data suppliers

Figure 2-9
SCENARIO 10b POLYGONS
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR001 APR 13/2012



***REMEDIAL ALTERNATIVES** (Polygons that correspond to sample numbers: JC-2, JC-7, JC-13, JC-18, JC-19)*	
1	No Action
2	Containment and 12-inch Removal/Disposal and Backfill: Pipe Containment of JC-7 (extend existing pipes 700 feet and backfill): Excavation with heavy equipment of remainder of Jefferson Canal polygons.
3	12-inch Removal/Disposal and Backfill: Excavation and backfill to existing grade: Do not modify the existing channel hydraulic characteristics

RE: 2010 Aerial by Microsoft Corp and its data suppliers

Note:
Refer to Appendix A to view pipelines at or near every Area of Investigation (AOI).

0 150 300 Feet

Figure 5-1
THIESSEN POLYGONS FOR JEFFERSON CANAL AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

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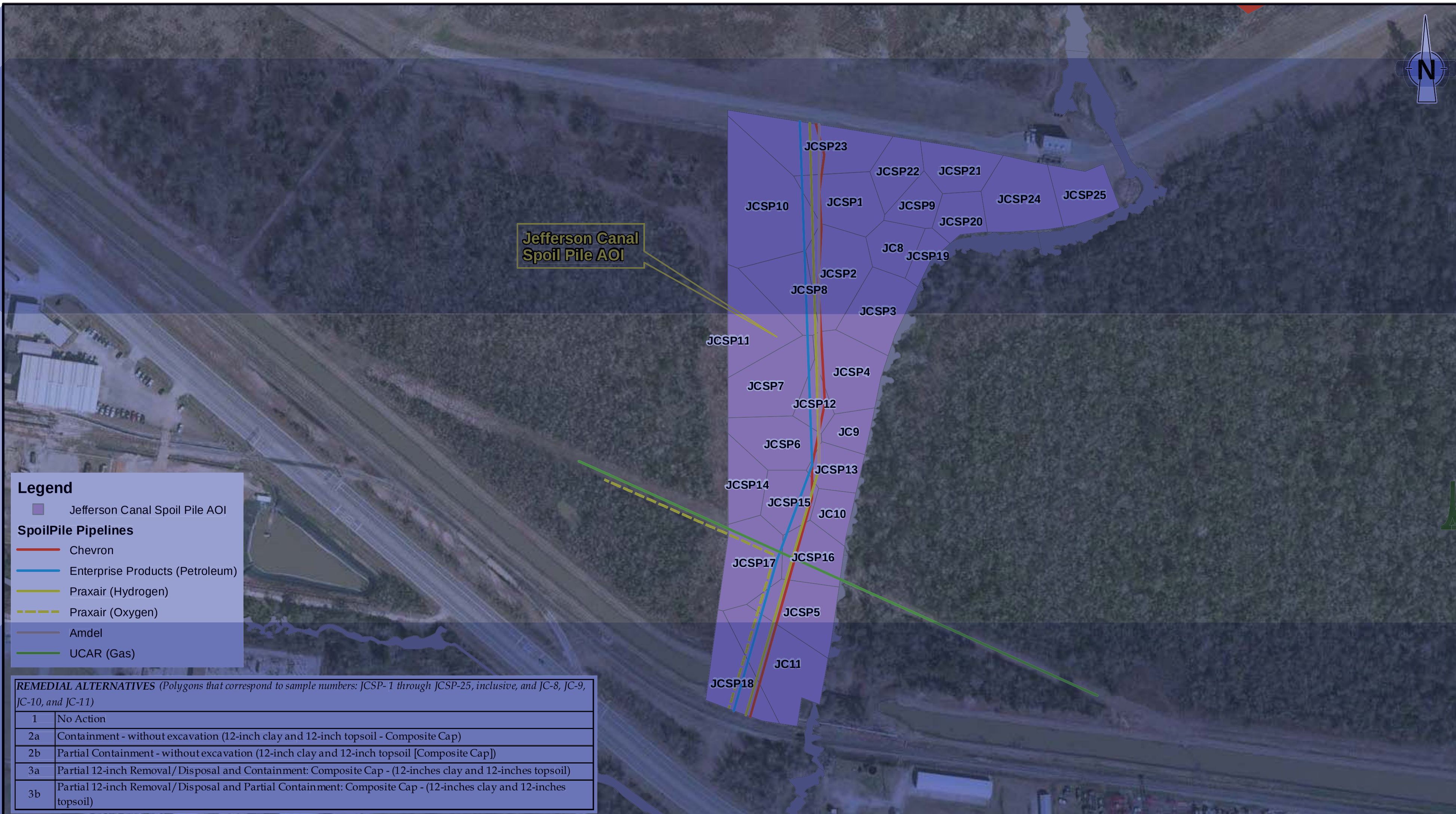


REMEDIAL ALTERNATIVES (Polygons that correspond to sample numbers: JCSP-1 through JCSP-25, inclusive, and JC-8, JC-9, JC-10, and JC-11)

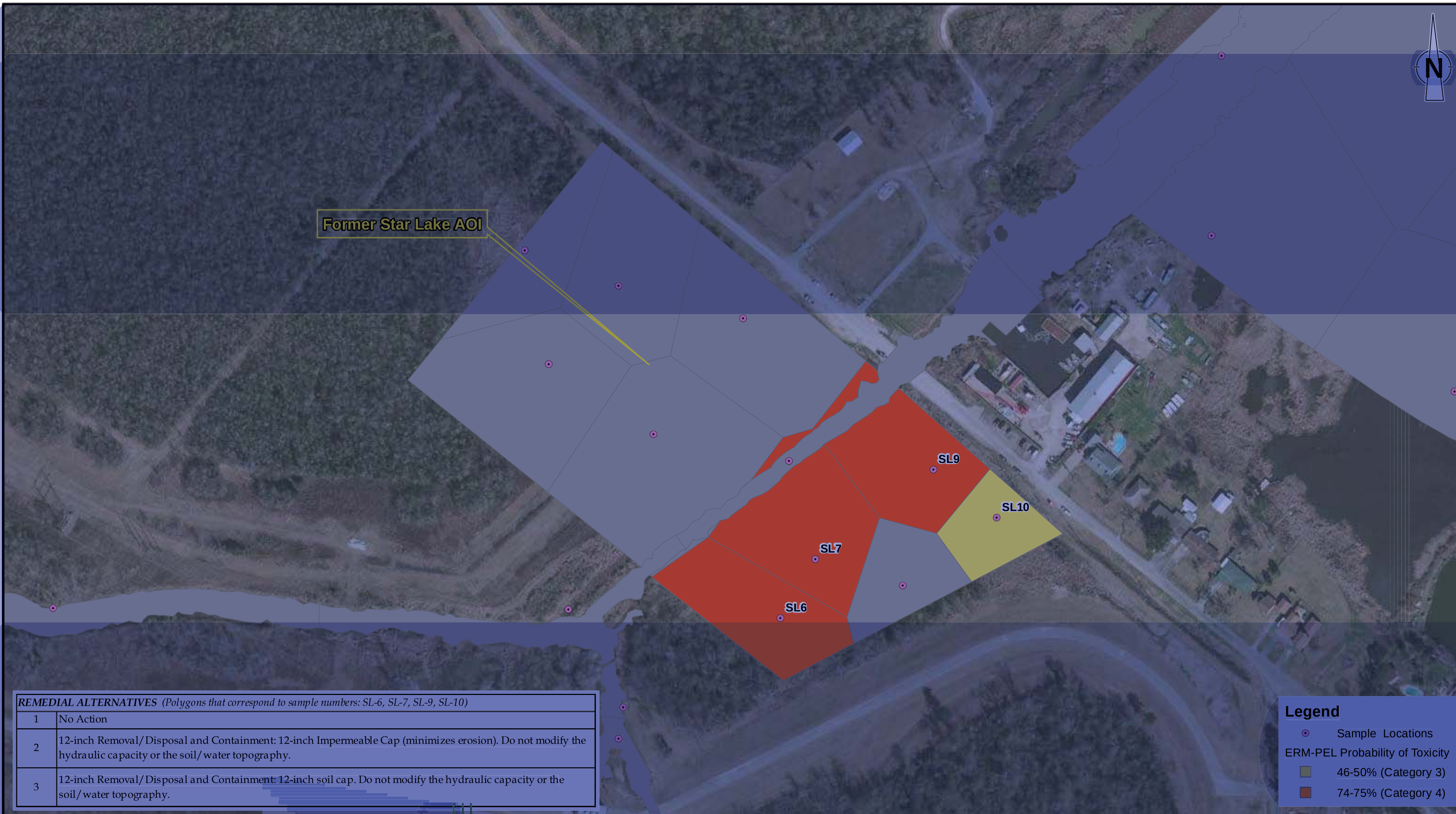
1	No Action
2a	Containment - without excavation (12-inch clay and 12-inch topsoil - Composite Cap)
2b	Partial Containment - without excavation (12-inch clay and 12-inch topsoil [Composite Cap])
3a	Partial 12-inch Removal/Disposal and Containment: Composite Cap - (12-inches clay and 12-inches topsoil)
3b	Partial 12-inch Removal/Disposal and Partial Containment: Composite Cap - (12-inches clay and 12-inches topsoil)

RE: 2010 Aerial by Microsoft Corp and its data suppliers

Note:
Refer to Appendix A to view pipelines at or near every Area of Investigation (AOI).

Figure 5-2
THIESSEN POLYGONS FOR JEFFERSON CANAL SPOIL PILE AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR013 APR 13/2012



REMEDIAL ALTERNATIVES *(Polygons that correspond to sample numbers: SL-6, SL-7, SL-9, SL-10)*	
1	No Action
2	12-inch Removal/Disposal and Containment: 12-inch Impermeable Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
3	12-inch Removal/Disposal and Containment: 12-inch soil cap. Do not modify the hydraulic capacity or the soil/water topography.

RE: 2010 Aerial by Microsoft Corp and its data suppliers

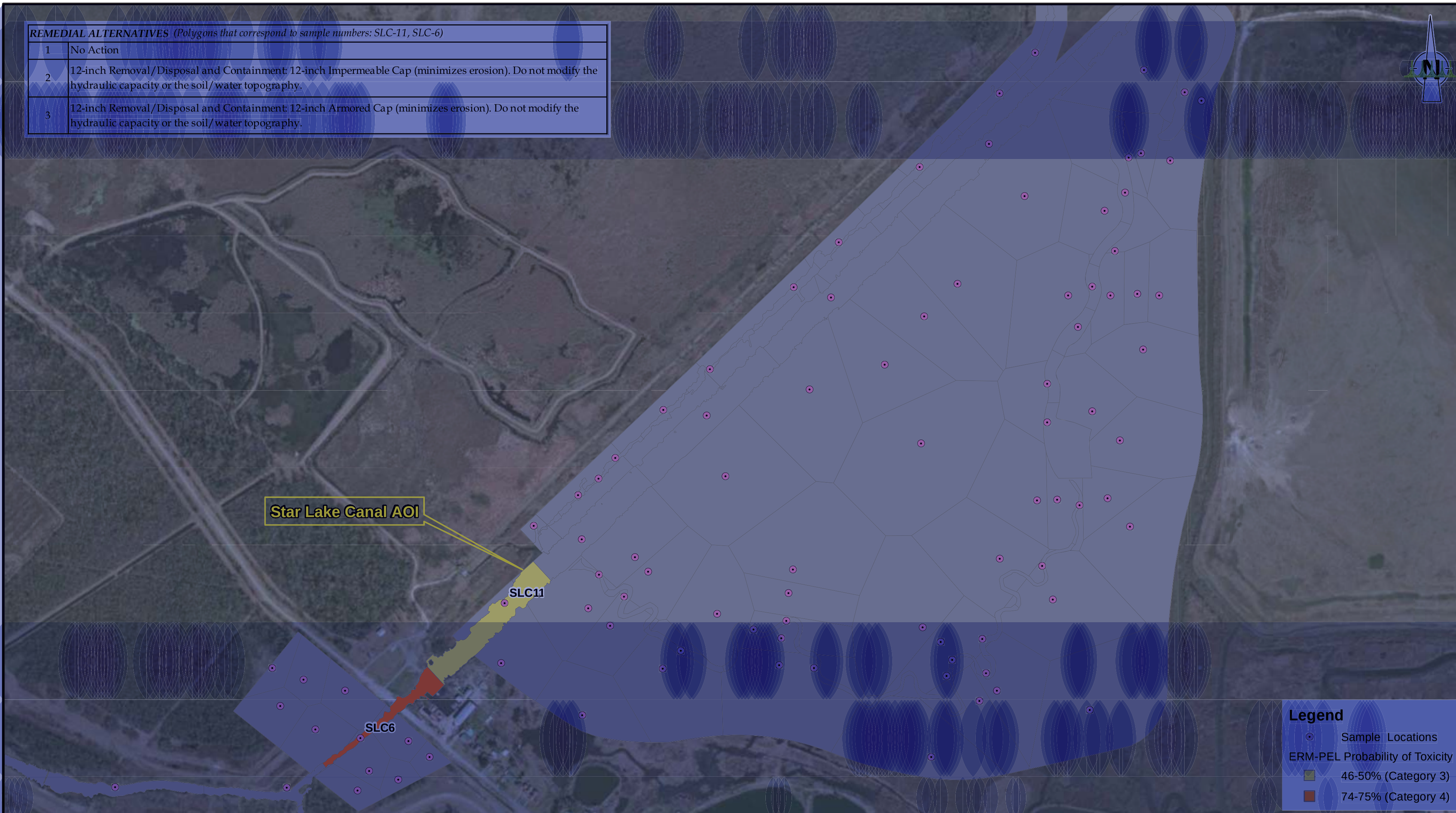
Note:
Refer to Appendix A to view pipelines at or near every Area of Investigation (AOI).

0 100 200 Feet

Figure 5-3
THIESSEN POLYGONS FOR FORMER STAR LAKE AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR014 APR 10/2012

REMEDIAL ALTERNATIVES *(Polygons that correspond to sample numbers: SLC-11, SLC-6)*		
1	No Action	
2	12-inch Removal/Disposal and Containment: 12-inch Impermeable Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.	
3	12-inch Removal/Disposal and Containment: 12-inch Armored Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.	



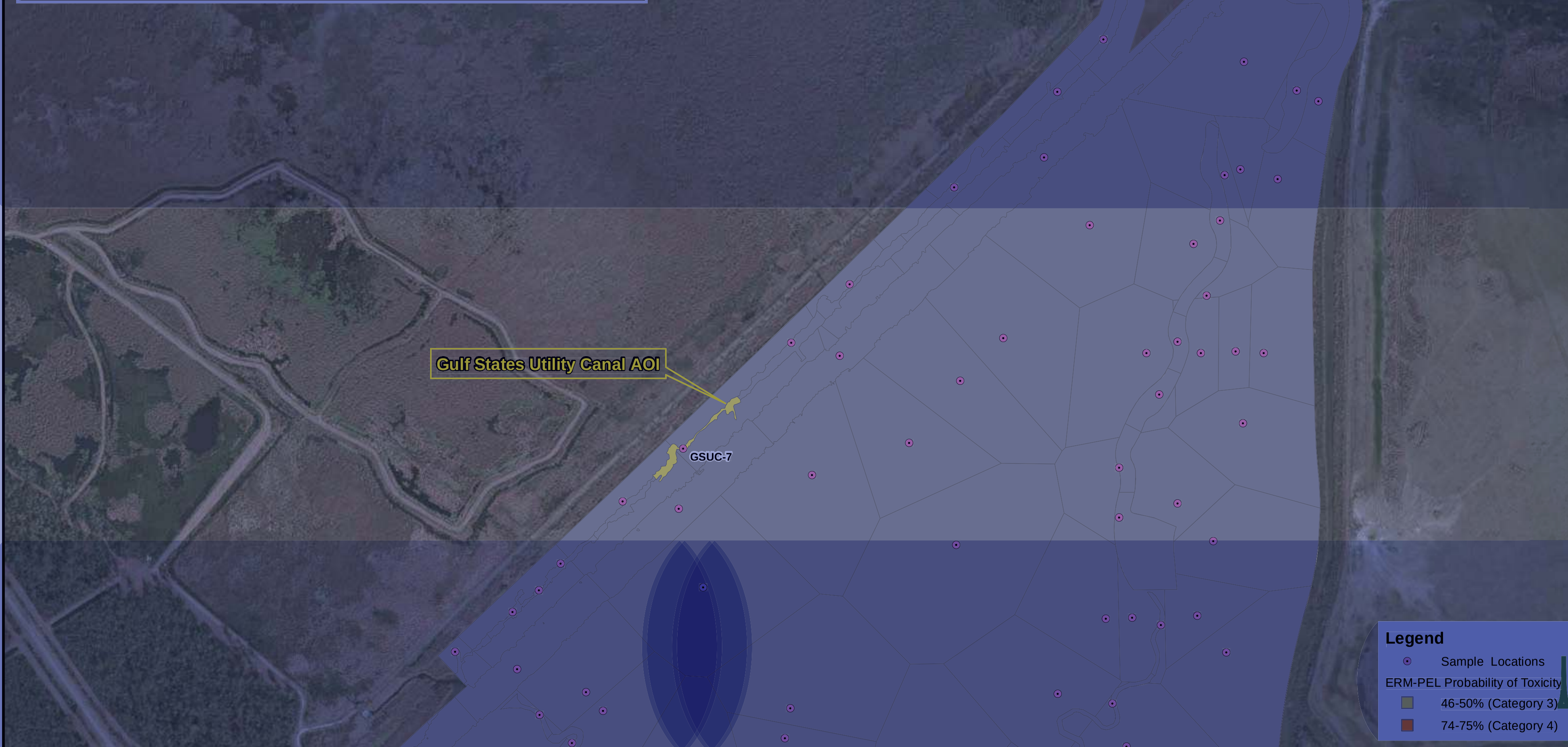
RE: 2010 Aerial by Microsoft Corp and its data suppliers

Note:
Refer to Appendix A to view pipelines at or near every Area of Investigation (AOI).

Figure 5-4
THIESSEN POLYGONS FOR STAR LAKE CANAL AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR015 APR 13/2012

REMEDIAL ALTERNATIVES *(Polygons that correspond to sample number: GSUC-7)*	
1	No Action
2	Containment - without excavation: 12-inch Composite cap
3	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
4	12-inch Removal/Disposal



RE: 2010 Aerial by Microsoft Corp and its data suppliers

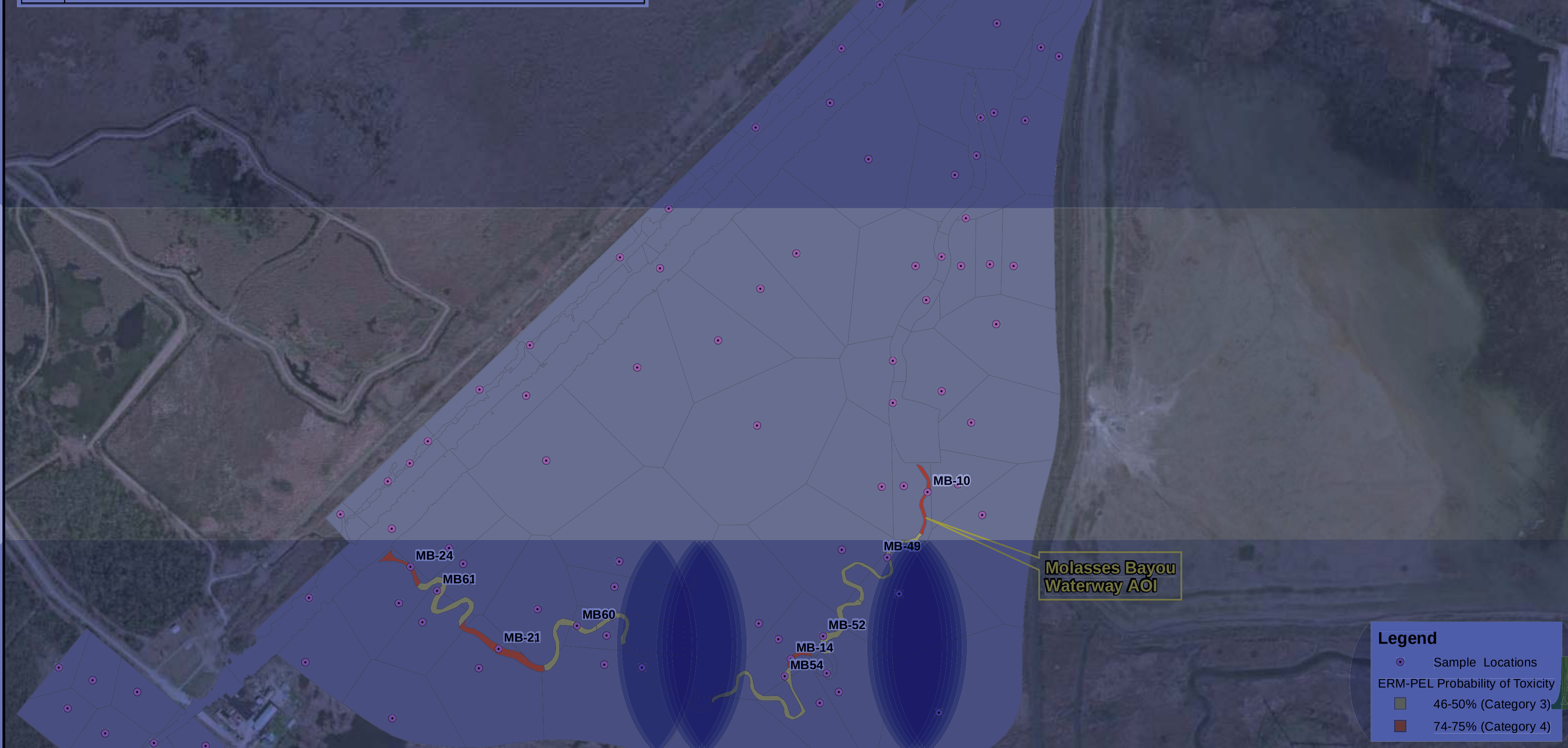
Note:
Refer to Appendix A to view pipelines at or near every Area of Investigation (AOI).

0 250 500 Feet

Figure 5-5
THIESSEN POLYGONS FOR GULF STATES UTILITY CANAL AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR016 APR 10/2012

REMEDIAL ALTERNATIVES *(Polygons that correspond to sample numbers: MB-10, MB-14, MB-18/MB-18R, MB-21, MB-24, MB-49, MB-52, MB-54, MB-60, MB-61)*	
1	No Action
2	Monitored Natural Recovery (10-year duration of measurement)
3	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.



RE: 2010 Aerial by Microsoft Corp and its data suppliers

Figure 5-6
THIESSEN POLYGONS FOR MOLASSES BAYOU WATERWAY AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR017 Mar 29/2012

REMEDIAL ALTERNATIVES *(Polygons that correspond to sample numbers: MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, MB-63)*

1	No Action
2	Monitored Natural Recovery (10-year duration of measurement)
3	Containment - without excavation: 12-inch Composite cap
4	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
5	12-inch Removal/Disposal

RE: 2010 Aerial by Microsoft Corp and its data suppliers

Figure 5-7
THIESSEN POLYGONS FOR MOLASSES BAYOU WETLAND AOI
STAR LAKE CANAL SUPERFUND SITE, JEFFERSON COUNTY, TEXAS
Chevron Environmental Management Company, Houston, Texas

27545-00(019)PR-BR018 APR 13/2012

TABLES

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Raccoon			*Muskrat*		
COPECS	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*
VOCs						
2-Butanone	6.08E-04	1.22E-04	2.72E-04	7.06E-04	1.41E-04	3.16E-04
Benzene	3.98E-04	7.96E-05	1.78E-04	2.83E-05	5.66E-06	1.26E-05
Carbon Disulfide	9.80E-03	1.96E-03	4.38E-03	1.51E-03	3.02E-04	6.76E-04
Carbon tetrachloride	1.96E-03	3.92E-04	8.76E-04	1.99E-04	3.98E-05	8.90E-05
cis-1,2-Dichloroethene	4.15E-05	8.29E-06	1.85E-05	1.30E-05	2.60E-06	5.82E-06
Ethylbenzene	3.19E-03	6.38E-04	1.43E-03	9.28E-05	1.86E-05	4.15E-05
Methyl Tert Butyl Ether	1.50E-05	3.01E-06	6.73E-06	2.78E-05	5.57E-06	1.25E-05
Xylene, m&p-	9.75E-05	1.95E-05	4.36E-05	4.82E-06	9.64E-07	2.15E-06
Xylene, o-	2.63E-05	5.25E-06	1.17E-05	4.76E-06	9.52E-07	2.13E-06
SVOCs						
2,4,6-Trichlorophenol	8.02E-04	1.60E-04	3.59E-04	9.77E-04	1.95E-04	4.37E-04
2, 4-Dichlorophenol	2.19E-02	4.39E-03	9.81E-03	4.77E-02	9.54E-03	2.13E-02
4-Chloro-3-methylphenol	1.03E-01	2.06E-02	4.60E-02	7.80E-02	1.56E-02	3.49E-02
Acetophenone	9.65E-05	1.93E-05	4.32E-05	7.95E-05	1.59E-05	3.55E-05
Atrazine	3.98E-03	7.97E-04	1.78E-03	4.69E-03	9.37E-04	2.10E-03
Benzaldehyde	1.17E-02	2.35E-03	5.25E-03	2.48E-06	4.97E-07	1.11E-06
Biphenyl	4.83E-02	9.65E-03	2.16E-02	1.89E-03	3.78E-04	8.46E-04
bis(2-Chloroethyl)ether	4.81E-03	9.62E-04	2.15E-03	5.67E-03	1.13E-03	2.53E-03
bis(2-Ethylhexyl)phthalate	1.53E-02	1.15E-03	4.19E-03	1.25E-03	9.34E-05	3.41E-04
Carbazole	4.22E-03	8.45E-04	1.89E-03	5.69E-03	1.14E-03	2.54E-03
Dibenzofuran	1.39E-02	2.78E-03	6.22E-03	9.57E-05	1.91E-05	4.28E-05
Hexachlorobenzene	**5.60E+01**	**1.12E+01**	**2.50E+01**	6.81E-01	1.36E-01	3.05E-01
Hexachlorobutadiene	3.80E-01	7.60E-02	1.70E-01	6.47E-01	1.29E-01	2.89E-01
Nitrobenzene	1.04E-01	2.08E-02	4.64E-02	1.45E-01	2.90E-02	6.49E-02
Pentachlorophenol	**6.28E+01**	**1.26E+01**	**2.81E+01**	2.45E-01	4.91E-02	1.10E-01
PAHs						
Total PAHs	**1.02E+01**	2.23E-02	4.77E-01	**2.00E+00**	3.99E-01	8.93E-01
PCBs						
Total PCBs	2.30E-01	4.90E-02	--	8.60E-02	1.80E-02	--
PCB Congeners (ΣTEQ_{PCB})	**1.50E+00**	1.50E-01	--	1.60E-01	1.60E-02	--
Pesticides						
4,4'-DDE	3.00E-03	6.00E-04	1.34E-03	8.70E-04	1.74E-04	3.89E-04
4,4'-DDT	4.87E-03	9.75E-04	2.18E-03	2.61E-03	5.22E-04	1.17E-03
Aldrin	3.09E-03	6.18E-04	1.38E-03	3.65E-03	7.31E-04	1.63E-03
alpha-Chlordane	3.94E-03	7.88E-04	1.76E-03	2.65E-03	5.29E-05	3.74E-04
alpha-BHC	7.08E-05	1.42E-05	3.17E-05	9.26E-05	1.85E-05	4.14E-05
beta-BHC	3.28E-03	6.56E-04	1.47E-03	7.67E-04	1.53E-04	3.43E-04
delta-BHC	4.20E-04	8.41E-05	1.88E-04	2.37E-04	4.75E-05	1.06E-04
Dieldrin	4.30E-03	8.61E-04	1.93E-03	3.66E-03	7.31E-04	1.64E-03
Endosulfan I	1.63E-01	3.27E-02	7.31E-02	4.88E-02	9.77E-03	2.18E-02
Endosulfan II	**2.87E+00**	5.74E-01	**1.28E+00**	7.31E-02	1.46E-02	3.27E-02
Endosulfan sulfate	1.04E-01	2.08E-02	4.65E-02	7.34E-02	1.47E-02	3.28E-02
Endrin	2.28E-02	4.55E-03	1.02E-02	4.30E-03	8.60E-04	1.92E-03
Endrin aldehyde	3.89E-03	7.78E-04	1.74E-03	4.34E-03	8.68E-04	1.94E-03
Endrin ketone	5.28E-03	1.06E-03	2.36E-03	4.30E-03	8.60E-04	1.92E-03
gamma-BHC (Lindane)	2.07E-04	4.15E-05	9.27E-05	1.27E-04	2.54E-05	5.67E-05
gamma-Chlordane	2.50E-02	5.00E-03	1.12E-02	2.65E-03	5.29E-04	1.18E-03
Heptachlor	2.00E-04	4.00E-05	8.96E-05	1.96E-04	3.92E-05	8.77E-05
Heptachlor epoxide	1.90E-03	3.79E-04	8.47E-04	1.96E-04	3.92E-05	8.77E-05
Methoxychlor	3.73E-04	7.46E-05	1.67E-04	1.06E-04	2.12E-05	4.74E-05
Toxaphene	4.52E-03	9.04E-04	2.02E-03	2.28E-03	4.56E-04	1.02E-03
Metals						
Aluminum	**2.37E+01**	**4.75E+00**	**1.06E+01**	**4.81E+00**	9.63E-01	**2.15E+00**
Antimony	6.93E-02	1.39E-02	3.10E-02	1.93E-01	3.87E-02	8.65E-02
Arsenic	1.77E-01	3.54E-02	7.92E-02	2.19E-01	4.38E-02	9.79E-02
Barium	5.06E-01	1.01E-01	2.26E-01	3.68E-01	7.35E-02	1.64E-01
Beryllium	2.21E-02	4.42E-03	9.87E-03	3.35E-02	6.69E-03	1.50E-02
Cadmium	6.53E-02	1.31E-02	2.92E-02	1.55E-01	3.09E-02	6.92E-02
Chromium Total (reporting III)	1.89E-01	3.78E-02	8.45E-02	4.27E-02	8.53E-03	1.91E-02
Chromium VI	**4.01E+00**	8.02E-01	**1.79E+00**	**1.13E+01**	**2.26E+00**	**5.05E+00**
Cobalt	3.54E-01	7.08E-02	1.58E-01	1.14E-01	2.28E-02	5.09E-02
Copper	5.42E-01	1.08E-01	2.43E-01	4.71E-01	9.42E-02	2.11E-01
Lead	**1.12E+00**	2.25E-01	5.03E-01	2.28E-01	4.56E-02	1.02E-01
Manganese	**5.44E+00**	**1.09E+00**	**2.43E+00**	**6.15E+00**	**1.23E+00**	**2.75E+00**
Mercury	6.52E-02	1.30E-02	2.91E-02	6.06E-03	1.21E-03	2.71E-03
Methyl Mercury	9.57E-02	1.91E-02	4.28E-02	4.21E-03	8.41E-04	1.88E-03
Nickel	6.89E-03	1.38E-03	3.08E-03	1.43E-02	2.85E-03	6.37E-03
Selenium	**2.84E+01**	**5.67E+00**	**1.27E+01**	**2.65E+01**	**5.31E+00**	**1.19E+01**
Silver	5.69E-03	1.14E-03	2.55E-03	1.04E-02	2.08E-03	4.65E-03
Vanadium	**7.25E+00**	**1.45E+00**	**3.24E+00**	**1.41E+00**	2.82E-01	6.31E-01
Zinc	1.98E-01	3.96E-02	8.86E-02	2.90E-01	5.80E-02	1.30E-01

Notes:
- COPEC = Constituent of Potential Ecological Concern
- VOC = Volatile Organic Compound
- SVOC = Semi-Volatile Organic Compound
- PAH = Polycyclic Aromatic Hydrocarbon
- PCB = Polychlorinated Biphenyl
- HQ = Hazard Quotient
- NOAEL = No Observed Adverse Effects Level
- LOAEL = Low Observed Adverse Effects Level
- GMATC = Geometric Maximum Allowable Toxicant Concentration
- -- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
- Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Short-tailed shrew			*American robin*		
COPECS	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*
VOCs						
2-Butanone	9.40E-04	1.88E-04	4.21E-04	1.19E-02	2.38E-03	5.32E-03
Benzene	4.26E-04	4.26E-05	1.35E-04	9.79E-03	9.79E-04	3.10E-03
Carbon Disulfide	1.31E-02	2.63E-03	5.86E-03	1.29E-01	2.58E-02	5.75E-02
Carbon tetrachloride	2.18E-03	4.37E-04	9.77E-04	5.32E-03	1.06E-03	2.38E-03
cis-1,2-Dichloroethene	6.23E-05	1.25E-05	2.79E-05	4.11E-04	8.22E-05	1.84E-04
Ethylbenzene	6.47E-03	1.29E-03	2.89E-03	4.20E-02	8.40E-03	1.88E-02
Methyl Tert Butyl Ether	1.58E-05	3.17E-06	7.09E-06	9.76E-05	1.95E-05	4.37E-05
Xylene, m&p-	1.93E-04	3.86E-05	8.63E-05	2.83E-04	5.66E-05	1.26E-04
Xylene, o-	3.21E-05	6.43E-06	1.44E-05	2.83E-04	5.65E-05	1.26E-04
SVOCs						
2,4,6-Trichlorophenol	3.03E-04	6.05E-05	1.35E-04	1.50E-02	3.01E-03	6.73E-03
2, 4-Dichlorophenol	1.26E-02	2.51E-03	5.62E-03	8.78E-03	1.76E-03	3.93E-03
4-Chloro-3-methylphenol	8.41E-02	1.68E-02	3.76E-02	1.28E-01	2.57E-02	5.74E-02
Acetophenone	9.07E-05	1.81E-05	4.06E-05	2.07E-03	4.13E-04	9.24E-04
Atrazine	7.39E-03	1.48E-03	3.31E-03	4.04E-03	8.09E-04	1.81E-03
Benzaldehyde	1.49E-02	2.97E-03	6.64E-03	2.76E-01	5.52E-02	1.23E-01
Biphenyl	5.89E-03	1.96E-03	3.40E-03	1.58E-03	4.64E-04	8.55E-04
bis(2-Chloroethyl)ether	1.79E-03	8.94E-04	1.26E-03	1.97E-02	9.87E-03	1.40E-02
bis(2-Ethylhexyl)phthalate	5.21E-01	1.04E-01	2.33E-01	7.51E-03	1.50E-03	3.36E-03
Carbazole	1.69E-03	3.37E-04	7.54E-04	1.92E-02	3.84E-03	8.59E-03
Dibenzofuran	7.69E-03	1.54E-03	3.44E-03	3.49E-02	6.97E-03	1.56E-02
Hexachlorobenzene	**1.36E+01**	**2.73E+00**	**6.10E+00**	5.93E-01	1.19E-01	2.65E-01
Hexachlorobutadiene	1.78E-01	3.56E-02	7.96E-02	3.76E-02	7.52E-03	1.68E-02
Nitrobenzene	7.58E-02	1.52E-02	3.39E-02	**1.69E+00**	3.38E-01	7.56E-01
Pentachlorophenol	**7.89E+01**	**1.58E+01**	**3.53E+01**	4.69E-02	9.37E-03	2.10E-02
PAHs						
Total PAHs	**5.80E+01**	**1.19E+01**	**2.62E+01**	4.17E-02	8.35E-03	1.87E-02
PCBs						
Total PCBs	5.90E-01	1.30E-01	--	9.00E-02	2.30E-02	--
PCB Congeners (ΣTEQ_{PCB})	**4.30E+00**	4.30E-01	--	3.50E-01	3.50E-02	--
Pesticides						
4,4'-DDE	2.76E-03	5.52E-04	1.23E-03	7.27E-02	1.45E-02	3.25E-02
4,4'-DDT	1.69E-02	3.38E-03	7.55E-03	6.15E-03	1.23E-03	2.75E-03
Aldrin	2.65E-02	5.29E-03	1.18E-02	1.04E-02	2.08E-03	4.64E-03
alpha-Chlordane	3.84E-04	5.29E-03	1.72E-04	5.95E-02	1.19E-02	2.66E-02
alpha-BHC	5.98E-05	1.20E-05	2.67E-05	5.40E-03	1.08E-03	2.42E-03
beta-BHC	7.55E-04	1.32E-04	3.16E-04	1.38E-03	2.76E-04	6.17E-04
delta-BHC	3.71E-04	8.57E-05	1.78E-04	3.91E-03	7.82E-04	1.75E-03
Dieldrin	6.59E-02	1.32E-02	2.95E-02	5.43E-02	1.09E-02	2.43E-02
Endosulfan I	5.17E-02	1.03E-02	2.31E-02	2.09E-01	4.17E-02	9.34E-02
Endosulfan II	5.41E-01	1.08E-01	2.42E-01	3.49E-01	6.98E-02	1.56E-01
Endosulfan sulfate	8.02E-02	1.60E-02	3.59E-02	6.68E-01	1.34E-01	2.99E-01
Endrin	1.85E-02	3.70E-03	8.27E-03	**1.06E+00**	2.12E-01	4.74E-01
Endrin aldehyde	2.83E-03	5.67E-04	1.27E-03	1.38E-01	2.77E-02	6.19E-02
Endrin ketone	4.27E-03	8.55E-04	1.91E-03	2.07E-01	4.14E-02	9.25E-02
gamma-BHC (Lindane)	5.62E-04	1.30E-04	2.70E-04	4.87E-03	9.75E-04	2.18E-03
gamma-Chlordane	4.19E-03	8.37E-04	1.87E-03	6.12E-01	1.22E-01	2.74E-01
Heptachlor	7.01E-04	1.40E-04	3.13E-04	7.21E-04	1.44E-04	3.22E-04
Heptachlor epoxide	8.11E-03	1.62E-03	3.63E-03	1.56E-02	3.11E-03	6.96E-03
Methoxychlor	2.36E-03	4.72E-04	1.05E-03	8.64E-04	1.73E-04	3.86E-04
Toxaphene	2.57E-02	5.14E-03	1.15E-02	1.89E-01	3.78E-02	8.46E-02
Metals						
Aluminum	**7.61E+01**	**1.52E+01**	**3.40E+01**	**1.50E+03**	**3.00E+02**	**6.71E+02**
Antimony	**1.23E+00**	2.46E-01	5.50E-01	**1.82E+01**	**3.63E+00**	**8.12E+00**
Arsenic	4.62E-01	9.23E-02	2.06E-01	1.84E-01	3.67E-02	8.21E-02
Barium	8.33E-02	1.67E-02	3.72E-02	7.30E-01	1.46E-01	3.27E-01
Beryllium	1.85E-03	3.71E-04	8.29E-04	2.45E-02	4.91E-03	1.10E-02
Cadmium	2.17E-01	4.35E-02	9.72E-02	**4.17E+00**	8.35E-01	**1.87E+00**
Chromium Total (reporting III)	4.73E-02	9.47E-03	2.12E-02	**7.58E+00**	**1.52E+00**	**3.39E+00**
Chromium VI	4.75E-01	9.59E-02	2.13E-01	**1.52E+01**	**3.03E+00**	**6.78E+00**
Cobalt	3.25E-01	6.51E-02	1.45E-01	3.78E-01	7.56E-02	1.69E-01
Copper	4.87E-01	9.73E-02	2.18E-01	**7.56E+00**	**1.51E+00**	**3.38E+00**
Lead	**5.83E+00**	**1.17E+00**	**2.61E+00**	**1.26E+01**	**2.52E+00**	**5.64E+00**
Manganese	9.86E-01	1.97E-01	4.41E-01	**8.64E+00**	**1.73E+00**	**3.38E+00**
Mercury	3.87E-03	7.74E-04	1.73E-03	6.15E-02	6.15E-02	1.38E-01
Methyl Mercury	1.41E-01	2.81E-02	6.29E-02	5.40E-03	1.08E-03	2.42E-03
Nickel	1.36E-02	2.72E-03	6.09E-03	5.21E-02	1.04E-02	2.33E-02
Selenium	**6.33E+00**	**1.27E+00**	**2.83E+00**	**3.38E+00**	6.76E-01	**1.51E+00**
Silver	2.02E-03	4.04E-04	9.03E-04	2.36E-01	4.71E-02	1.05E-01
Vanadium	**4.16E+00**	**2.08E+00**	**2.94E+00**	**8.88E+00**	**1.78E+00**	**3.97E+00**
Zinc	5.76E-01	1.15E-01	2.58E-01	8.24E-01	1.65E-01	3.68E-01

Notes:
- COPEC = Constituent of Potential Ecological Concern
- VOC = Volatile Organic Compound
- SVOC = Semi-Volatile Organic Compound
- PAH = Polycyclic Aromatic Hydrocarbon
- PCB = Polychlorinated Biphenyl
- HQ = Hazard Quotient
- NOAEL = No Observed Adverse Effects Level
- LOAEL = Low Observed Adverse Effects Level
- GMATC = Geometric Maximum Allowable Toxicant Concentration
- -- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
- Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Belted kingfisher			*Brown pelican*		
COPECS	$HQ_{[NOAEL]}$	$HQ_{[LOAEL]}$	$HQ_{[GMATC]}$	$HQ_{[NOAEL]}$	$HQ_{[LOAEL]}$	$HQ_{[GMATC]}$
VOCs						
2-Butanone	4.20E-03	8.40E-04	1.88E-03	1.44E-05	2.88E-06	6.44E-06
Benzene	1.10E-03	1.10E-04	3.47E-04	3.55E-06	3.55E-07	1.12E-06
Carbon Disulfide	1.37E-01	2.75E-02	6.14E-02	4.54E-04	9.11E-05	2.03E-04
Carbon tetrachloride	7.54E-03	1.51E-03	3.37E-03	1.87E-05	3.74E-06	8.37E-06
cis-1,2-Dichloroethene	4.53E-04	9.05E-05	2.02E-04	1.44E-06	2.88E-07	6.43E-07
Ethylbenzene	1.10E-01	2.21E-02	4.94E-02	1.49E-04	2.97E-05	6.64E-05
Methyl Tert Butyl Ether	6.81E-05	1.36E-05	3.05E-05	1.99E-07	3.98E-08	8.89E-08
Xylene, m&p-	4.60E-04	9.20E-05	2.06E-04	1.01E-06	2.03E-07	4.53E-07
Xylene, o-	2.99E-04	5.97E-05	1.34E-04	1.01E-06	2.02E-07	4.53E-07
SVOCs						
2,4,6-Trichlorophenol	1.14E-02	2.28E-03	5.11E-03	3.83E-05	7.65E-06	1.71E-05
2, 4-Dichlorophenol	6.47E-03	1.29E-03	2.89E-03	2.17E-05	4.34E-06	9.70E-06
4-Chloro-3-methylphenol	1.10E-02	2.20E-03	4.92E-03	3.71E-05	7.43E-06	1.66E-05
Acetophenone	3.44E-04	6.88E-05	1.54E-04	1.13E-06	2.26E-07	5.04E-07
Atrazine	3.03E-03	6.05E-04	1.35E-03	1.02E-05	2.04E-06	4.55E-06
Benzaldehyde	**1.18E+00**	2.36E-01	5.28E-01	1.42E-03	2.84E-04	6.36E-04
Biphenyl	2.49E-03	7.33E-04	1.35E-03	4.39E-06	1.29E-06	2.38E-06
bis(2-Chloroethyl)ether	1.47E-02	7.34E-03	1.04E-02	4.91E-05	2.46E-05	3.47E-05
bis(2-Ethylhexyl)phthalate	5.43E-03	1.09E-03	2.43E-03	3.08E-05	6.15E-06	1.38E-05
Carbazole	1.55E-02	3.10E-03	6.94E-03	4.75E-05	9.49E-06	2.12E-05
Dibenzofuran	3.13E-03	6.25E-04	1.40E-03	1.08E-05	2.16E-06	4.82E-06
Hexachlorobenzene	8.73E-02	1.75E-02	3.91E-02	3.59E-04	7.18E-05	1.61E-04
Hexachlorobutadiene	3.21E-02	6.41E-03	1.43E-02	9.37E-05	1.87E-05	4.19E-05
Nitrobenzene	3.79E-01	7.58E-02	1.69E-01	1.27E-03	2.53E-04	5.66E-04
Pentachlorophenol	3.47E-02	6.95E-03	1.55E-02	1.15E-04	2.30E-05	5.13E-05
PAHs						
Total PAHs	4.55E-02	9.09E-03	2.03E-02	1.42E-04	2.83E-05	6.33E-05
PCBs						
Total PCBs	7.80E-03	2.00E-03	--	1.20E-04	3.00E-05	--
PCB Congeners (ΣTEQ_{PCB})	2.10E-02	2.10E-03	--	1.80E-04	1.80E-05	--
Pesticides						
4,4'-DDE	7.47E-03	1.49E-03	3.34E-03	5.63E-06	1.13E-06	2.52E-06
4,4'-DDT	2.25E-04	4.50E-05	1.01E-04	2.38E-06	4.77E-07	1.07E-06
Aldrin	2.80E-03	5.60E-04	1.25E-03	7.72E-04	1.54E-04	3.45E-04
alpha-Chlordane	3.67E-02	7.35E-03	1.64E-02	5.87E-06	1.17E-06	2.63E-06
alpha-BHC	1.69E-03	3.38E-04	7.56E-04	1.60E-05	3.20E-06	7.17E-06
beta-BHC	1.41E-04	2.83E-05	6.33E-05	1.55E-06	3.10E-07	6.94E-07
delta-BHC	1.05E-03	2.10E-04	4.70E-04	1.24E-05	2.49E-06	5.56E-06
Dieldrin	1.05E-01	2.10E-02	4.70E-02	3.13E-04	6.26E-05	1.40E-04
Endosulfan I	1.47E-01	2.94E-02	6.57E-02	4.24E-04	8.47E-05	1.89E-04
Endosulfan II	7.37E-01	1.47E-01	3.29E-01	1.36E-03	2.72E-04	6.09E-04
Endosulfan sulfate	5.33E-02	1.07E-02	2.38E-02	6.06E-04	1.21E-04	2.71E-04
Endrin	3.26E-02	6.52E-03	1.46E-02	2.87E-04	5.74E-05	1.28E-04
Endrin aldehyde	1.44E-01	2.89E-02	6.46E-02	2.78E-04	5.55E-05	1.24E-04
Endrin ketone	5.28E-02	1.06E-02	2.36E-02	2.75E-04	5.50E-05	1.23E-04
gamma-BHC (Lindane)	1.55E-03	3.11E-04	6.95E-04	6.58E-06	1.32E-06	2.94E-06
gamma-Chlordane	7.60E-03	1.52E-03	3.40E-03	6.73E-06	1.35E-06	3.01E-06
Heptachlor	2.56E-04	5.12E-05	1.14E-04	1.06E-05	2.13E-06	4.76E-06
Heptachlor epoxide	1.72E-04	3.44E-05	7.69E-05	1.15E-05	2.30E-06	5.14E-06
Methoxychlor	2.14E-04	4.28E-05	9.57E-05	1.94E-06	3.89E-07	8.70E-07
Toxaphene	2.28E-01	4.57E-02	1.02E-01	3.17E-04	6.33E-05	1.42E-04
Metals						
Aluminum	**1.14E+02**	**2.29E+01**	**5.12E+01**	2.78E-02	5.56E-03	1.24E-02
Antimony	**9.98E+00**	**2.00E+00**	**4.46E+00**	3.34E-02	6.67E-03	1.49E-02
Arsenic	8.11E-02	1.62E-02	3.63E-02	1.40E-03	2.81E-04	6.27E-04
Barium	7.21E-01	1.44E-01	3.23E-01	1.07E-03	2.15E-04	4.80E-04
Beryllium	9.51E-03	1.90E-03	4.25E-03	3.18E-05	6.36E-06	1.42E-05
Cadmium	**1.36E+00**	2.71E-01	6.07E-01	5.63E-04	1.13E-04	2.52E-04
Chromium Total (reporting III)	**1.37E+00**	2.74E-01	6.13E-01	5.41E-03	1.08E-03	2.42E-03
Chromium VI	**3.26E+00**	6.52E-01	**1.46E+00**	3.30E-03	6.59E-04	1.47E-03
Cobalt	7.81E-02	1.56E-02	3.49E-02	2.84E-04	5.68E-05	1.27E-04
Copper	**5.18E+00**	**1.04E+00**	**2.32E+00**	1.18E-03	2.35E-04	5.26E-04
Lead	6.59E-01	1.32E-01	2.95E-01	1.74E-03	3.47E-04	7.77E-04
Manganese	**3.90E+00**	7.80E-01	**1.74E+00**	6.67E-03	1.33E-03	2.98E-03
Mercury	6.37E-02	1.27E-02	2.85E-02	3.17E-04	6.33E-05	1.42E-04
Methyl Mercury	5.37E-03	1.07E-03	2.40E-03	1.61E-04	3.21E-05	7.18E-05
Nickel	1.40E-02	2.80E-03	6.26E-03	2.79E-05	5.58E-06	1.25E-05
Selenium	**1.71E+00**	3.43E-01	7.67E-01	1.20E-03	2.39E-04	5.34E-04
Silver	1.09E-01	2.18E-02	4.87E-02	3.60E-04	7.21E-05	1.61E-04
Vanadium	**1.44E+00**	2.88E-01	6.44E-01	4.30E-03	8.61E-04	1.93E-03
Zinc	4.32E-01	8.63E-02	1.93E-01	6.23E-03	1.25E-03	2.79E-03

Notes:
COPEC = Constituent of Potential Ecological Concern
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
PAH = Polycyclic Aromatic Hydrocarbon
PCB = Polychlorinated Biphenyl
HQ = Hazard Quotient
NOAEL = No Observed Adverse Effects Level
LOAEL = Low Observed Adverse Effects Level
GMATC = Geometric Maximum Allowable Toxicant Concentration
-- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Green heron			*Mallard*		
COPECS	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*
VOCs						
2-Butanone	4.61E-04	9.23E-05	2.06E-04	7.65E-05	1.53E-05	3.42E-05
Benzene	1.19E-04	1.19E-05	3.75E-05	3.10E-06	3.10E-07	9.81E-07
Carbon Disulfide	1.30E-02	2.61E-03	5.83E-03	1.68E-04	3.36E-05	7.51E-05
Carbon tetrachloride	7.31E-04	1.46E-04	3.27E-04	2.09E-04	4.18E-05	9.34E-05
cis-1,2-Dichloroethene	4.88E-05	9.75E-06	2.18E-05	1.42E-06	2.83E-07	6.34E-07
Ethylbenzene	2.64E-02	5.27E-03	1.18E-02	1.95E-04	3.90E-05	8.72E-05
Methyl Tert Butyl Ether	9.17E-06	1.83E-06	4.10E-06	3.01E-06	6.02E-07	1.35E-06
Xylene, m&p-	8.91E-05	1.78E-05	3.99E-05	1.16E-06	2.31E-07	5.17E-07
Xylene, o-	2.84E-05	5.68E-06	1.27E-05	9.07E-07	1.81E-07	4.06E-07
SVOCs						
2,4,6-Trichlorophenol	1.08E-03	2.17E-04	4.85E-04	4.72E-04	9.44E-05	2.11E-04
2,4-Dichlorophenol	6.12E-04	1.22E-04	2.74E-04	2.82E-04	5.64E-05	1.26E-04
4-Chloro-3-methylphenol	1.04E-03	2.08E-04	4.66E-04	4.62E-04	9.24E-05	2.07E-04
Acetophenone	3.62E-05	7.25E-06	1.62E-05	8.70E-06	1.74E-06	3.89E-06
Atrazine	2.87E-04	5.75E-05	1.29E-04	2.54E-05	5.09E-06	1.14E-05
Benzaldehyde	9.10E-02	1.82E-02	4.07E-02	6.81E-06	1.36E-06	3.04E-06
Biphenyl	2.08E-04	6.12E-05	1.13E-04	1.10E-04	3.23E-05	5.96E-05
bis(2-Chloroethyl)ether	1.39E-03	6.95E-04	9.83E-04	6.17E-04	3.08E-04	4.36E-04
bis(2-Ethylhexyl)phthalate	1.15E-03	2.29E-04	5.13E-04	9.05E-03	1.81E-03	4.05E-03
Carbazole	1.33E-03	2.67E-04	5.97E-04	6.24E-04	1.25E-04	2.79E-04
Dibenzofuran	2.91E-04	5.83E-05	1.30E-04	2.58E-04	5.15E-05	1.15E-04
Hexachlorobenzene	7.97E-03	1.59E-03	3.56E-03	**5.02E+00**	**1.00E+00**	**2.24E+00**
Hexachlorobutadiene	2.65E-03	5.30E-04	1.19E-03	1.18E-03	2.35E-04	5.26E-04
Nitrobenzene	3.59E-02	7.18E-03	1.61E-02	1.59E-02	3.18E-03	7.10E-03
Pentachlorophenol	3.29E-03	6.59E-04	1.47E-03	8.12E-01	1.62E-01	3.63E-01
PAHs						
Total PAHs	4.98E-03	9.96E-04	2.23E-03	2.55E-03	5.09E-04	1.14E-03
PCBs						
Total PCBs	5.20E-04	1.30E-04	--	4.10E-04	1.00E-04	--
PCB Congeners (ΣTEQ_{PCB})	1.30E-03	1.30E-04	--	9.60E-04	9.60E-05	--
Pesticides						
4,4'-DDE	1.44E-04	2.88E-05	6.45E-05	5.96E-05	1.19E-05	2.67E-05
4,4'-DDT	2.75E-05	5.49E-06	1.23E-05	1.78E-04	3.55E-05	7.94E-05
Aldrin	1.11E-02	2.23E-03	4.98E-03	4.06E-03	8.11E-04	1.81E-03
alpha-Chlordane	1.70E-04	3.39E-05	7.59E-05	2.36E-05	4.72E-06	1.05E-05
alpha-BHC	2.20E-04	4.41E-05	9.85E-05	8.56E-05	1.71E-05	3.83E-05
beta-BHC	1.43E-05	2.86E-06	6.39E-06	7.79E-06	1.56E-06	3.48E-06
delta-BHC	1.53E-04	3.06E-05	6.84E-05	1.27E-05	2.53E-06	5.67E-06
Dieldrin	8.60E-03	1.72E-03	3.85E-03	2.09E-05	4.18E-06	9.35E-06
Endosulfan I	1.32E-02	2.64E-03	5.90E-03	4.44E-04	8.87E-05	1.98E-04
Endosulfan II	5.88E-02	1.18E-02	2.63E-02	5.55E-03	1.11E-03	2.48E-03
Endosulfan sulfate	7.19E-03	1.44E-03	3.22E-03	6.13E-04	1.23E-04	2.74E-04
Endrin	3.21E-03	6.43E-04	1.44E-03	1.02E-03	2.04E-04	4.57E-04
Endrin aldehyde	9.29E-03	1.86E-03	4.15E-03	2.93E-04	5.87E-05	1.31E-04
Endrin ketone	4.21E-03	8.43E-04	1.88E-03	3.73E-04	7.47E-05	1.67E-04
gamma-BHC (Lindane)	1.52E-04	3.04E-05	6.80E-05	6.81E-06	1.36E-06	3.05E-06
gamma-Chlordane	5.46E-05	1.09E-05	2.44E-05	8.56E-05	1.71E-05	3.83E-05
Heptachlor	1.13E-04	2.26E-05	5.06E-05	6.27E-05	1.25E-05	2.80E-05
Heptachlor epoxide	7.59E-05	1.52E-05	3.39E-05	5.78E-05	1.16E-05	2.58E-05
Methoxychlor	4.15E-05	8.30E-06	1.86E-05	3.68E-05	7.36E-06	1.65E-05
Toxaphene	1.89E-02	3.78E-03	8.45E-03	2.19E-03	4.38E-04	9.80E-04
Metals						
Aluminum	5.27E-01	1.05E-01	2.36E-01	**1.31E+00**	2.63E-01	5.88E-01
Antimony	9.46E-01	1.89E-01	4.23E-01	8.50E-01	1.70E-01	3.80E-01
Arsenic	1.09E-01	2.17E-02	4.85E-02	6.17E-03	1.23E-03	2.76E-03
Barium	6.86E-02	1.37E-02	3.07E-02	9.91E-03	1.98E-03	4.43E-03
Beryllium	9.01E-04	1.80E-04	4.03E-04	8.56E-04	1.71E-04	3.83E-04
Cadmium	1.60E-02	3.19E-03	7.14E-03	2.95E-03	5.90E-04	1.32E-03
Chromium Total (reporting III)	1.10E-01	2.21E-02	4.93E-02	9.83E-03	1.97E-03	4.40E-03
Chromium VI	2.29E-01	4.58E-02	1.02E-01	5.43E-02	1.09E-02	2.43E-02
Cobalt	6.64E-03	1.33E-03	2.97E-03	2.06E-03	4.13E-04	9.23E-04
Copper	5.28E-02	1.06E-02	2.36E-02	2.84E-03	5.69E-04	1.27E-03
Lead	1.14E-01	2.29E-02	5.12E-02	2.14E-02	4.28E-03	9.57E-03
Manganese	3.77E-01	7.54E-02	1.69E-01	4.10E-01	8.19E-02	1.83E-01
Mercury	3.55E-03	7.09E-04	1.59E-03	2.14E-03	4.29E-04	9.59E-04
Methyl Mercury	1.19E-02	2.37E-03	5.30E-03	2.21E-04	4.41E-05	9.86E-05
Nickel	1.32E-03	2.65E-04	5.92E-04	3.42E-04	6.84E-05	1.53E-04
Selenium	3.25E-02	6.50E-03	1.45E-02	2.94E-02	5.87E-03	1.31E-02
Silver	1.04E-02	2.08E-03	4.64E-03	1.83E-03	3.67E-04	8.21E-04
Vanadium	9.62E-02	1.92E-02	4.30E-02	2.15E-02	4.30E-03	9.61E-03
Zinc	2.81E-01	5.62E-02	1.26E-01	1.65E-02	3.30E-03	7.37E-03

Notes:
COPEC = Constituent of Potential Ecological Concern
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
PAH = Polycyclic Aromatic Hydrocarbon
PCB = Polychlorinated Biphenyl
HQ = Hazard Quotient
NOAEL = No Observed Adverse Effects Level
LOAEL = Low Observed Adverse Effects Level
GMATC = Geometric Maximum Allowable Toxicant Concentration
-- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Marsh wren			*Reddish egret*		
COPECS	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*
VOCs						
2-Butanone	2.40E-02	4.80E-03	1.07E-02	2.49E-04	4.99E-05	1.12E-04
Benzene	4.94E-03	4.94E-04	1.56E-03	7.26E-05	7.26E-06	2.30E-05
Carbon Disulfide	3.75E-01	7.51E-02	1.68E-01	9.56E-03	1.92E-03	4.28E-03
Carbon tetrachloride	2.61E-02	5.21E-03	1.17E-02	5.70E-04	1.14E-04	2.55E-04
cis-1,2-Dichloroethene	2.03E-03	4.06E-04	9.08E-04	3.00E-05	6.00E-06	1.34E-05
Ethylbenzene	**2.40E+00**	4.80E-01	**1.07E+00**	4.00E-03	8.00E-04	1.79E-03
Methyl Tert Butyl Ether	5.44E-04	1.09E-04	2.43E-04	4.07E-06	8.14E-07	1.82E-06
Xylene, m&p-	7.27E-03	1.45E-03	3.25E-03	2.09E-05	4.18E-06	9.34E-06
Xylene, o-	8.38E-04	1.68E-04	3.75E-04	2.09E-05	4.17E-06	9.33E-06
SVOCs						
2,4,6-Trichlorophenol	3.01E-02	6.02E-03	1.35E-02	7.81E-04	1.56E-04	3.49E-04
2, 4-Dichlorophenol	1.70E-02	3.41E-03	7.62E-03	4.83E-04	9.65E-05	2.16E-04
4-Chloro-3-methylphenol	2.91E-02	5.81E-03	1.30E-02	7.50E-04	1.50E-04	3.36E-04
Acetophenone	1.16E-03	2.31E-04	5.17E-04	2.16E-05	4.33E-06	9.67E-06
Atrazine	8.02E-03	1.60E-03	3.59E-03	2.07E-04	4.14E-05	9.25E-05
Benzaldehyde	2.65E-01	5.28E-02	1.18E-01	1.16E-01	2.32E-02	5.20E-02
Biphenyl	3.52E-03	1.03E-03	1.91E-03	2.10E-04	6.19E-05	1.14E-04
bis(2-Chloroethyl)ether	3.85E-02	1.93E-02	2.72E-02	1.00E-03	5.02E-04	7.10E-04
bis(2-Ethylhexyl)phthalate	1.51E-02	3.02E-03	6.75E-03	6.99E-04	1.40E-04	3.13E-04
Carbazole	3.71E-02	7.42E-03	1.66E-02	9.62E-04	1.92E-04	4.30E-04
Dibenzofuran	8.10E-03	1.62E-03	3.62E-03	2.10E-04	4.20E-05	9.40E-05
Hexachlorobenzene	**7.58E+00**	**1.52E+00**	**3.39E+00**	6.91E-03	1.38E-03	3.09E-03
Hexachlorobutadiene	7.43E-02	1.49E-02	3.32E-02	1.91E-03	3.82E-04	8.54E-04
Nitrobenzene	9.99E-01	2.00E-01	4.47E-01	2.59E-02	5.19E-03	1.16E-02
Pentachlorophenol	9.83E-01	1.97E-01	4.39E-01	2.38E-03	4.76E-04	1.06E-03
PAHs						
Total PAHs	4.45E-02	8.91E-03	1.99E-02	3.00E-03	6.01E-04	1.34E-03
PCBs						
Total PCBs	2.40E-02	6.00E-03	--	1.10E-03	2.80E-04	--
PCB Congeners (ΣTEQ_{PCB})	1.60E-01	1.60E-02	--	2.30E-03	2.30E-04	--
Pesticides						
4,4'-DDE	2.20E-02	4.40E-03	9.84E-03	1.25E-04	2.49E-05	5.57E-05
4,4'-DDT	2.09E-03	4.17E-04	9.33E-04	9.89E-06	1.98E-06	4.42E-06
Aldrin	3.48E-02	6.96E-03	1.56E-02	3.18E-03	6.36E-04	1.42E-03
alpha-Chlordane	2.31E-02	4.62E-03	1.03E-02	2.02E-04	4.03E-05	9.02E-05
alpha-BHC	1.29E-02	2.58E-03	5.77E-03	1.06E-04	2.12E-05	4.75E-05
beta-BHC	8.47E-04	1.69E-04	3.79E-04	6.47E-06	1.29E-06	2.89E-06
delta-BHC	1.08E-02	2.17E-03	4.84E-03	4.94E-05	9.89E-06	2.21E-05
Dieldrin	1.06E-01	2.12E-02	4.74E-02	9.90E-03	1.98E-03	4.43E-03
Endosulfan I	3.23E-01	6.45E-02	1.44E-01	7.09E-02	1.42E-02	3.17E-02
Endosulfan II	6.71E-01	1.34E-01	3.00E-01	7.12E-02	1.42E-02	3.18E-02
Endosulfan sulfate	4.56E-01	9.12E-02	2.04E-01	2.94E-03	5.88E-04	1.31E-03
Endrin	3.41E-01	6.82E-02	1.52E-01	1.17E-03	2.34E-04	5.24E-04
Endrin aldehyde	2.98E-01	5.97E-02	1.33E-01	9.24E-03	1.85E-03	4.13E-03
Endrin ketone	3.01E-01	6.02E-02	1.35E-01	2.54E-03	5.07E-04	1.13E-03
gamma-BHC (Lindane)	2.12E-03	4.25E-04	9.50E-04	7.65E-05	1.53E-05	3.42E-05
gamma-Chlordane	7.13E-02	1.43E-02	3.19E-02	1.98E-05	3.97E-06	8.87E-06
Heptachlor	4.95E-04	9.91E-05	2.22E-04	1.03E-04	2.05E-05	4.59E-05
Heptachlor epoxide	6.11E-04	1.22E-04	2.73E-04	4.60E-05	9.19E-06	2.06E-05
Methoxychlor	9.51E-04	1.90E-04	4.25E-04	3.69E-05	7.39E-06	1.65E-05
Toxaphene	2.46E-01	4.91E-02	1.10E-01	2.16E-02	4.31E-03	9.64E-03
Metals						
Aluminum	**6.84E+01**	**1.37E+01**	**3.06E+01**	6.32E-01	1.26E-01	2.83E-01
Antimony	**2.63E+01**	**5.26E+00**	**1.18E+01**	6.83E-01	1.37E-01	3.05E-01
Arsenic	**1.02E+00**	2.03E-01	4.55E-01	3.49E-02	6.98E-03	1.56E-02
Barium	1.49E-01	2.97E-02	6.64E-02	2.69E-02	5.38E-03	1.20E-02
Beryllium	2.55E-02	5.09E-03	1.14E-02	6.51E-04	1.30E-04	2.91E-04
Cadmium	**3.57E+00**	7.14E-01	**1.60E+00**	1.15E-02	2.31E-03	5.16E-03
Chromium Total (reporting III)	8.53E-01	1.71E-01	3.81E-01	8.22E-02	1.64E-02	3.67E-02
Chromium VI	**4.36E+01**	**8.71E+00**	**1.95E+01**	6.75E-02	1.35E-02	3.02E-02
Cobalt	2.04E-01	4.08E-02	9.13E-02	4.90E-03	9.79E-04	2.19E-03
Copper	**1.91E+01**	**3.83E+00**	**8.56E+00**	2.39E-02	4.78E-03	1.07E-02
Lead	7.98E-01	1.60E-01	3.57E-01	1.24E-01	2.48E-02	5.55E-02
Manganese	**2.69E+00**	5.38E-01	**1.20E+00**	1.93E-01	3.87E-02	8.65E-02
Mercury	1.07E-01	2.13E-02	4.77E-02	3.44E-01	4.08E-04	9.12E-04
Methyl Mercury	1.74E-02	3.48E-03	7.78E-03	1.27E-02	2.54E-03	5.68E-03
Nickel	1.06E-02	2.12E-03	4.73E-03	6.94E-04	1.39E-04	3.10E-04
Selenium	**4.53E+00**	9.06E-01	**2.03E+00**	2.39E-02	4.78E-03	1.07E-02
Silver	3.02E-01	6.03E-02	1.35E-01	7.38E-03	1.48E-03	3.30E-03
Vanadium	8.06E-01	1.61E-01	3.61E-01	1.14E-01	2.27E-02	5.08E-02
Zinc	**1.88E+00**	3.75E-01	8.40E-01	1.79E-01	3.59E-02	8.03E-02

Notes:
COPEC = Constituent of Potential Ecological Concern
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
PAH = Polycyclic Aromatic Hydrocarbon
PCB = Polychlorinated Biphenyl
HQ = Hazard Quotient
NOAEL = No Observed Adverse Effects Level
LOAEL = Low Observed Adverse Effects Level
GMATC = Geometric Maximum Allowable Toxicant Concentration
-- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Spotted sandpiper			*White-faced ibis*		
COPECS	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*
VOCs						
2-Butanone	1.80E-02	3.61E-03	8.07E-03	1.17E-03	2.35E-04	5.24E-04
Benzene	4.93E-03	4.93E-04	1.56E-03	6.30E-04	6.30E-05	1.99E-04
Carbon Disulfide	**2.48E+00**	4.98E-01	**1.11E+00**	1.61E-03	3.23E-04	7.22E-04
Carbon tetrachloride	2.21E-02	4.42E-03	9.88E-03	9.03E-04	1.81E-04	4.04E-04
cis-1,2-Dichloroethene	1.48E-03	2.97E-04	6.64E-04	7.14E-05	1.43E-05	3.19E-05
Ethylbenzene	**1.58E+00**	3.15E-01	7.05E-01	6.22E-02	1.24E-02	2.78E-02
Methyl Tert Butyl Ether	3.76E-04	7.51E-05	1.68E-04	1.64E-05	3.29E-06	7.35E-06
Xylene, m&p-	4.84E-03	9.67E-04	2.16E-03	1.96E-04	3.93E-05	8.79E-05
Xylene, o-	6.66E-04	1.33E-04	2.98E-04	3.54E-05	7.08E-06	1.58E-05
SVOCs						
2,4,6-Trichlorophenol	2.40E-02	4.80E-03	1.07E-02	1.26E-03	2.52E-04	5.63E-04
2, 4-Dichlorophenol	1.36E-02	2.72E-03	6.09E-03	7.15E-04	1.43E-04	3.20E-04
4-Chloro-3-methylphenol	4.02E-02	8.04E-03	1.80E-02	7.10E-03	1.42E-03	3.18E-03
Acetophenone	1.15E-03	2.30E-04	5.14E-04	1.31E-04	2.62E-05	5.86E-05
Atrazine	6.40E-03	1.28E-03	2.86E-03	3.35E-04	6.71E-05	1.50E-04
Benzaldehyde	4.56E-01	9.10E-02	2.04E-01	2.09E-02	4.18E-03	9.36E-03
Biphenyl	3.67E-03	1.08E-03	1.99E-03	1.51E-04	4.45E-05	8.20E-05
bis(2-Chloroethyl)ether	3.08E-02	1.54E-02	2.18E-02	1.63E-03	8.14E-04	1.15E-03
bis(2-Ethylhexyl)phthalate	4.82E-02	9.64E-03	2.16E-02	3.20E-03	6.41E-04	1.43E-03
Carbazole	2.97E-02	5.94E-03	1.33E-02	1.57E-03	3.13E-04	7.00E-04
Dibenzofuran	**4.57E+01**	**9.14E+00**	**2.04E+01**	5.70E-04	1.14E-04	2.55E-04
Hexachlorobenzene	**9.57E+00**	**1.91E+00**	**4.28E+00**	1.77E-01	3.54E-02	7.92E-02
Hexachlorobutadiene	6.03E-02	1.21E-02	2.70E-02	3.11E-03	6.22E-04	1.39E-03
Nitrobenzene	8.01E-01	1.60E-01	3.58E-01	1.03E-01	2.07E-02	4.62E-02
Pentachlorophenol	**1.11E+00**	2.22E-01	4.96E-01	2.41E-02	4.81E-03	1.08E-02
PAHs						
Total PAHs	1.87E-01	3.73E-02	8.34E-02	1.52E-02	3.04E-03	6.79E-03
PCBs						
Total PCBs	9.80E-02	2.50E-02	--	4.40E-03	1.10E-03	--
PCB Congeners ($\sum TEQ_{PCB}$)	6.50E-01	6.50E-02	--	2.40E-02	2.40E-03	--
Pesticides						
4,4'-DDE	2.67E-02	5.33E-03	1.19E-02	8.40E-04	1.68E-04	3.76E-04
4,4'-DDT	2.30E-03	4.60E-04	1.03E-03	3.20E-04	6.40E-05	1.43E-04
Aldrin	2.44E-02	4.88E-03	1.09E-02	3.15E-02	6.30E-03	1.41E-02
alpha-Chlordane	3.09E-02	6.18E-03	1.38E-02	1.99E-04	3.99E-05	8.91E-05
alpha-BHC	9.40E-03	1.88E-03	4.20E-03	5.54E-04	1.11E-04	2.48E-04
beta-BHC	7.67E-04	1.53E-04	3.43E-04	4.88E-05	9.76E-06	2.18E-05
delta-BHC	7.71E-03	1.54E-03	3.45E-03	4.37E-04	8.74E-05	1.95E-04
Dieldrin	9.72E-02	1.94E-02	4.35E-02	5.05E-03	1.01E-03	2.26E-03
Endosulfan I	2.68E-01	5.37E-02	1.20E-01	1.77E-02	3.54E-03	7.92E-03
Endosulfan II	7.81E-01	1.56E-01	3.49E-01	3.83E-02	7.67E-03	1.71E-02
Endosulfan sulfate	4.01E-01	8.03E-02	1.80E-01	4.45E-02	8.91E-03	1.99E-02
Endrin	4.41E-01	8.82E-02	1.97E-01	4.53E-02	9.06E-03	2.03E-02
Endrin aldehyde	2.41E-01	4.82E-02	1.08E-01	9.61E-03	1.92E-03	4.30E-03
Endrin ketone	2.40E-01	4.80E-02	1.07E-01	1.23E-02	2.46E-03	5.50E-03
gamma-BHC (Lindane)	2.71E-03	5.43E-04	1.21E-03	2.86E-04	5.72E-05	1.28E-04
gamma-Chlordane	1.51E-01	3.01E-02	6.73E-02	1.95E-03	3.89E-04	8.70E-04
Heptachlor	4.71E-04	9.43E-05	2.11E-04	2.17E-04	4.33E-05	9.69E-05
Heptachlor epoxide	2.75E-03	5.50E-04	1.23E-03	4.10E-03	8.20E-04	1.83E-03
Methoxychlor	9.42E-04	1.88E-04	4.21E-04	1.28E-04	2.57E-05	5.74E-05
Toxaphene	2.35E-01	4.69E-02	1.05E-01	1.51E-02	3.02E-03	6.74E-03
Metals						
Aluminum	**3.05E+02**	**6.10E+01**	**1.36E+02**	**5.40E+00**	**1.08E+00**	**2.41E+00**
Antimony	**2.11E+01**	**4.23E+00**	**9.45E+00**	**1.11E+00**	2.23E-01	4.98E-01
Arsenic	6.97E-01	1.39E-01	3.12E-01	2.58E-01	5.17E-02	1.16E-01
Barium	5.74E-01	1.15E-01	2.57E-01	3.66E-02	7.32E-03	1.64E-02
Beryllium	2.20E-02	4.41E-03	9.86E-03	1.45E-03	2.89E-04	6.47E-04
Cadmium	**3.12E+00**	6.24E-01	**1.40E+00**	2.97E-02	5.94E-03	1.33E-02
Chromium Total (reporting III)	**2.23E+00**	4.46E-01	9.98E-01	3.90E-01	7.80E-02	1.75E-01
Chromium VI	**1.30E+02**	**2.60E+01**	**5.81E+01**	5.71E-01	1.14E-01	2.55E-01
Cobalt	2.03E-01	4.06E-02	9.09E-02	1.93E-02	3.86E-03	8.64E-03
Copper	**1.57E+01**	**3.14E+00**	**7.03E+00**	7.15E-02	1.43E-02	3.20E-02
Lead	**2.71E+00**	5.42E-01	**1.21E+00**	**1.35E+00**	2.71E-01	6.06E-01
Manganese	**4.22E+00**	8.44E-01	**1.89E+00**	2.81E-01	5.62E-02	1.26E-01
Mercury	1.24E-01	2.48E-02	5.55E-02	1.70E-02	3.40E-03	7.60E-03
Methyl Mercury	1.34E-02	2.68E-03	5.98E-03	1.64E-02	3.27E-03	7.32E-03
Nickel	1.92E-02	3.84E-03	8.59E-03	2.03E-03	4.06E-04	9.08E-04
Selenium	**3.67E+00**	7.34E-01	**1.64E+00**	3.93E-02	7.87E-03	1.76E-02
Silver	2.46E-01	4.91E-02	1.10E-01	1.41E-02	2.82E-03	6.30E-03
Vanadium	**2.25E+00**	4.50E-01	**1.01E+00**	4.20E-01	8.40E-02	1.88E-01
Zinc	**1.43E+00**	2.86E-01	6.39E-01	5.01E-01	1.00E-01	2.24E-01

Notes:
COPEC = Constituent of Potential Ecological Concern
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
PAH = Polycyclic Aromatic Hydrocarbon
PCB = Polychlorinated Biphenyl
HQ = Hazard Quotient
NOAEL = No Observed Adverse Effects Level
LOAEL = Low Observed Adverse Effects Level
GMATC = Geometric Maximum Allowable Toxicant Concentration
-- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p* -dioxin [2,3,7,8-TCDD]
Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

COPECS	*Wood stork* $HQ_{[NOAEL]}$	*Wood stork* $HQ_{[LOAEL]}$	*Wood stork* $HQ_{[GMATC]}$	*Bullfrog* $HQ_{[NOAEL]}$	*Bullfrog* $HQ_{[LOAEL]}$	*Bullfrog* $HQ_{[GMATC]}$
VOCs						
2-Butanone	8.09E-04	1.62E-04	3.62E-04	1.92E-03	3.84E-04	8.58E-04
Benzene	2.18E-04	2.18E-05	6.88E-05	4.76E-04	4.76E-05	1.51E-04
Carbon Disulfide	2.86E-02	5.74E-03	1.28E-02	5.49E-02	1.10E-02	2.46E-02
Carbon tetrachloride	1.64E-03	3.27E-04	7.32E-04	5.10E-03	1.02E-03	2.28E-03
cis-1,2-Dichloroethene	9.02E-05	1.80E-05	4.03E-05	1.96E-04	3.92E-05	8.76E-05
Ethylbenzene	1.19E-02	2.37E-03	5.31E-03	8.29E-01	1.66E-01	3.71E-01
Methyl Tert Butyl Ether	1.21E-05	2.42E-06	5.41E-06	3.48E-05	6.96E-06	1.56E-05
Xylene, m&p-	6.27E-05	1.25E-05	2.80E-05	2.97E-04	5.94E-05	1.33E-04
Xylene, o-	6.26E-05	1.25E-05	2.80E-05	1.19E-04	2.39E-05	5.34E-05
SVOCs						
2,4,6-Trichlorophenol	2.32E-03	4.64E-04	1.04E-03	4.30E-03	8.61E-04	1.93E-03
2, 4-Dichlorophenol	1.31E-03	2.62E-04	5.85E-04	2.50E-03	5.00E-04	1.12E-03
4-Chloro-3-methylphenol	2.23E-03	4.45E-04	9.96E-04	4.19E-03	8.38E-04	1.87E-03
Acetophenone	6.24E-05	1.25E-05	2.79E-05	1.53E-04	3.05E-05	6.83E-05
Atrazine	6.13E-04	1.23E-04	2.74E-04	2.54E-03	5.08E-04	1.13E-03
Benzaldehyde	3.33E-01	6.65E-02	1.49E-01	3.17E-01	6.33E-02	1.42E-01
Biphenyl	5.86E-03	1.72E-03	3.18E-03	8.66E-04	2.55E-04	4.70E-04
bis(2-Chloroethyl)ether	3.00E-03	1.50E-03	2.12E-03	5.97E-03	2.98E-03	4.22E-03
bis(2-Ethylhexyl)phthalate	2.02E-03	4.03E-04	9.01E-04	4.43E-02	8.86E-03	1.98E-02
Carbazole	3.09E-03	6.19E-04	1.38E-03	6.38E-03	1.28E-03	2.85E-03
Dibenzofuran	6.20E-04	1.24E-04	2.77E-04	1.31E-02	2.61E-03	5.84E-03
Hexachlorobenzene	2.11E-02	4.23E-03	9.45E-03	**6.94E+00**	**1.39E+00**	**3.11E+00**
Hexachlorobutadiene	6.33E-03	1.27E-03	2.83E-03	1.34E-01	2.68E-02	5.99E-02
Nitrobenzene	7.71E-02	1.54E-02	3.45E-02	1.58E-01	3.16E-02	7.07E-02
Pentachlorophenol	7.08E-03	1.42E-03	3.16E-03	4.22E-01	8.44E-02	1.89E-01
PAHs						
Total PAHs	8.99E-03	1.80E-03	4.02E-03	3.95E-02	7.90E-03	1.77E-02
PCBs						
Total PCBs	3.30E-03	8.40E-04	--	1.00E-01	2.70E-02	--
PCB Congeners (ΣTEQ_{PCB})	6.80E-03	6.80E-04	--	3.20E-02	3.20E-03	--
Pesticides						
4,4'-DDE	3.61E-04	7.22E-05	1.61E-04	2.22E-03	4.44E-04	9.92E-04
4,4'-DDT	3.22E-05	6.43E-06	1.44E-05	4.54E-03	9.09E-04	2.03E-03
Aldrin	9.83E-03	1.97E-03	4.39E-03	7.89E-02	1.58E-02	3.53E-02
alpha-Chlordane	5.81E-04	1.16E-04	2.60E-04	6.33E-03	1.27E-03	2.83E-03
alpha-BHC	3.19E-04	6.39E-05	1.43E-04	8.09E-03	1.62E-03	3.62E-03
beta-BHC	2.32E-05	4.65E-06	1.04E-05	6.84E-04	1.37E-04	3.06E-04
delta-BHC	1.59E-04	3.18E-05	7.11E-05	1.15E-03	2.30E-04	5.13E-04
Dieldrin	2.85E-02	5.71E-03	1.28E-02	8.53E-02	1.92E-03	1.28E-02
Endosulfan I	3.73E-02	7.47E-03	1.67E-02	9.36E-02	1.87E-02	4.19E-02
Endosulfan II	2.04E-01	4.09E-02	9.14E-02	4.35E-01	8.69E-02	1.94E-01
Endosulfan sulfate	8.90E-03	1.78E-03	3.98E-03	5.43E-02	1.09E-02	2.43E-02
Endrin	3.61E-03	7.23E-04	1.62E-03	3.85E-02	7.70E-03	1.72E-02
Endrin aldehyde	2.66E-02	5.32E-03	1.19E-02	9.42E-02	1.88E-02	4.21E-02
Endrin ketone	7.82E-03	1.56E-03	3.50E-03	4.62E-02	9.23E-03	2.06E-02
gamma-BHC (Lindane)	1.56E-04	3.12E-05	6.98E-05	1.49E-03	2.98E-04	6.67E-04
gamma-Chlordane	5.98E-05	1.20E-05	2.67E-05	2.42E-03	4.84E-04	1.08E-03
Heptachlor	3.04E-04	6.08E-05	1.36E-04	9.14E-04	1.83E-04	4.09E-04
Heptachlor epoxide	1.47E-04	2.94E-05	6.57E-05	6.74E-04	1.35E-04	3.02E-04
Methoxychlor	9.47E-05	1.89E-05	4.23E-05	1.64E-03	3.27E-04	7.31E-04
Toxaphene	6.20E-02	1.24E-02	2.77E-02	1.33E-01	1.33E-02	4.20E-02
Metals						
Aluminum	**1.82E+00**	3.63E-01	8.12E-01	**4.13E+00**	8.26E-01	**1.85E+00**
Antimony	**2.04E+00**	4.07E-01	9.10E-01	**4.05E+00**	8.10E-01	**1.81E+00**
Arsenic	1.03E-01	2.06E-02	4.61E-02	**3.67E+00**	7.34E-01	**1.64E+00**
Barium	6.33E-02	1.27E-02	2.83E-02	7.69E-01	1.54E-01	3.44E-01
Beryllium	1.94E-03	3.89E-04	8.69E-04	3.89E-03	7.78E-04	1.74E-03
Cadmium	6.55E-03	1.31E-03	2.93E-03	**2.20E+00**	3.99E-01	9.37E-01
Chromium Total (reporting III)	2.31E-01	4.61E-02	1.03E-01	**1.04E+00**	2.07E-01	4.64E-01
Chromium VI	1.86E-01	3.73E-02	8.33E-02	**3.92E+00**	7.84E-01	**1.75E+00**
Cobalt	1.45E-02	2.90E-03	6.48E-03	5.52E-02	1.10E-02	2.47E-02
Copper	6.59E-02	1.32E-02	2.95E-02	7.25E-01	1.45E-01	3.24E-01
Lead	3.59E-01	7.18E-02	1.60E-01	**2.24E+00**	4.47E-01	**1.00E+00**
Manganese	4.95E-01	9.90E-02	2.21E-01	**1.85E+01**	**3.71E+00**	**8.29E+00**
Mercury	6.68E-03	1.34E-03	2.99E-03	3.41E-02	6.82E-03	1.52E-02
Methyl Mercury	2.05E-02	4.10E-03	9.16E-03	6.63E-01	1.33E-01	2.97E-01
Nickel	1.89E-03	3.77E-04	8.43E-04	1.86E-01	3.72E-02	8.33E-02
Selenium	6.99E-02	1.40E-02	3.13E-02	**1.40E+00**	2.80E-01	6.26E-01
Silver	2.22E-02	4.43E-03	9.91E-03	8.73E-02	1.75E-02	3.91E-02
Vanadium	3.28E-01	6.56E-02	1.47E-01	**1.67E+00**	3.34E-01	7.46E-01
Zinc	5.37E-01	1.07E-01	2.40E-01	**1.91E+00**	3.82E-01	8.54E-01

Notes:
- COPEC = Constituent of Potential Ecological Concern
- VOC = Volatile Organic Compound
- SVOC = Semi-Volatile Organic Compound
- PAH = Polycyclic Aromatic Hydrocarbon
- PCB = Polychlorinated Biphenyl
- HQ = Hazard Quotient
- NOAEL = No Observed Adverse Effects Level
- LOAEL = Low Observed Adverse Effects Level
- GMATC = Geometric Maximum Allowable Toxicant Concentration
- -- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
- **Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis**

TABLE 2-1

HAZARD QUOTIENTS FOR RECEPTORS OF CONCERN
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

	Painted turtle		
COPECS	*HQ [NOAEL]*	*HQ [LOAEL]*	*HQ [GMATC]*
VOCs			
2-Butanone	4.46E-04	8.92E-05	1.99E-04
Benzene	1.01E-04	1.01E-05	3.20E-05
Carbon Disulfide	1.06E-02	2.13E-03	4.75E-03
Carbon tetrachloride	1.63E-03	3.26E-04	7.28E-04
cis-1,2-Dichloroethene	4.16E-05	8.32E-06	1.86E-05
Ethylbenzene	2.44E-01	4.89E-02	1.09E-01
Methyl Tert Butyl Ether	1.06E-05	2.12E-06	4.74E-06
Xylene, m&p-	8.14E-05	1.63E-05	3.64E-05
Xylene, o-	2.32E-05	4.64E-06	1.04E-05
SVOCs			
2,4,6-Trichlorophenol	1.18E-02	2.35E-03	5.26E-03
2, 4-Dichlorophenol	6.96E-03	1.39E-03	3.11E-03
4-Chloro-3-methylphenol	1.15E-02	2.31E-03	5.16E-03
Acetophenone	3.86E-05	7.72E-06	1.73E-05
Atrazine	7.00E-04	1.40E-04	3.13E-04
Benzaldehyde	5.19E-02	1.04E-02	2.32E-02
Biphenyl	2.02E-04	5.93E-05	1.09E-04
bis(2-Chloroethyl)ether	1.63E-03	8.17E-04	1.15E-03
bis(2-Ethylhexyl)phthalate	1.64E-02	3.28E-03	7.33E-03
Carbazole	1.59E-03	3.18E-04	7.11E-04
Dibenzofuran	4.62E-03	9.24E-04	2.07E-03
Hexachlorobenzene	**3.55E+00**	7.10E-01	**1.59E+00**
Hexachlorobutadiene	3.15E-02	6.31E-03	1.41E-02
Nitrobenzene	4.37E-02	8.75E-03	1.96E-02
Pentachlorophenol	**2.10E+00**	4.20E-01	9.39E-01
PAHs			
Total PAHs	1.18E-02	2.36E-03	5.28E-03
PCBs			
Total PCBs	3.70E-02	9.30E-03	--
PCB Congeners (ΣTEQ$_{PCB}$)	1.20E-02	3.20E-03	--
Pesticides			
4,4'-DDE	5.41E-04	1.08E-04	2.42E-04
4,4'-DDT	1.45E-02	2.91E-03	6.50E-03
Aldrin	2.64E-02	5.28E-03	1.18E-02
alpha-Chlordane	1.26E-03	2.52E-04	5.63E-04
alpha-BHC	2.53E-03	5.06E-04	1.13E-03
beta-BHC	1.89E-04	3.78E-05	8.45E-05
delta-BHC	3.74E-04	7.48E-05	1.67E-04
Dieldrin	1.17E-02	2.34E-03	5.23E-03
Endosulfan I	2.11E-02	4.21E-03	9.42E-03
Endosulfan II	8.12E-02	1.62E-02	3.63E-02
Endosulfan sulfate	1.78E-02	3.56E-03	7.95E-03
Endrin	1.25E-02	2.51E-03	5.61E-03
Endrin aldehyde	2.12E-02	4.24E-03	9.48E-03
Endrin ketone	1.28E-02	2.56E-03	5.73E-03
gamma-BHC (Lindane)	3.57E-04	7.15E-05	1.60E-04
gamma-Chlordane	7.83E-04	1.57E-04	3.50E-04
Heptachlor	2.57E-04	5.14E-05	1.15E-04
Heptachlor epoxide	2.17E-04	4.33E-05	9.69E-05
Methoxychlor	4.27E-04	8.54E-05	1.91E-04
Toxaphene	2.60E-02	2.60E-03	8.21E-03
Metals			
Aluminum	**2.42E+00**	4.84E-01	**1.08E+00**
Antimony	**1.44E+00**	2.89E-01	6.45E-01
Arsenic	**1.20E+00**	2.40E-01	5.36E-01
Barium	1.68E-01	3.36E-02	7.52E-02
Beryllium	1.38E-03	2.77E-04	6.18E-04
Cadmium	7.12E-02	1.42E-02	3.18E-02
Chromium Total (reporting III)	2.67E-01	5.34E-02	1.19E-01
Chromium VI	**1.91E+00**	3.82E-01	8.53E-01
Cobalt	2.54E-02	5.09E-03	1.14E-02
Copper	1.91E-01	3.81E-02	8.53E-02
Lead	6.96E-01	1.39E-01	3.11E-01
Manganese	**7.07E+00**	**1.41E+00**	**3.16E+00**
Mercury	9.49E-03	1.90E-03	4.25E-03
Methyl Mercury	1.17E-01	2.33E-02	5.21E-02
Nickel	7.26E-02	1.45E-02	3.25E-02
Selenium	4.98E-01	9.95E-02	2.23E-01
Silver	3.10E-02	6.20E-03	1.39E-02
Vanadium	6.69E-01	1.34E-01	2.99E-01
Zinc	5.01E-01	1.00E-01	2.24E-01

Notes:
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HQ = Hazard Quotient
NOAEL = No Observed Adverse Effects Level
LOAEL = Low Observed Adverse Effects Level
GMATC = Geometric Maximum Allowable Toxicant Concentration
-- = GMATC not evaluated as a toxicity equivalence factor to 2,3,7,8-tetrachlordibenzo-*p*-dioxin [2,3,7,8-TCDD]
Bold values indicate a COPEC-Receptor of Concern (ROC) pair retained in the Sensitivity Analysis

TABLE 2-2
DESCRIPTION OF REMEDIATION SCENARIOS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Scenario Number	*1*	*2*	*3a, 3b*	*4a, 4b*	*4c, 4d*
Scenario Description	No remediation	Remediate all of Jefferson Canal Spoil Pile	Remediate the top 5 hottest sediment samples and the top 5 Jefferson Canal Spoil Pile hot spots	Remediate top 10 sediment hot spots in Jefferson Canal and Former Star Lake and 6 Jefferson Canal Spoil Pile hot spots	Remediate top 10 sediment hot spots in Jefferson Canal and Former Star Lake, 3 hot spots in Molasses Bayou, and 6 Jefferson Canal Spoil Pile hot spots
Remediated Sediment Polygons	None	None	JC-7, JC-18, MB-21, MB-28, MB-63	JC-7, JC-18, SL-7, JC-21, JC-6, JC-13, JC-2, SL-6, JC-3, JC-15	JC-7, JC-18, SL-7, JC-21, JC-6, JC-13, JC-2, SL-6, JC-3, JC-15, MB-21, MB-28, MB-63
Remediated Soil Polygons	None	All	JCSP-3, JCSP-19, JC-8, JCSP-5, JCSP-9	JCSP-9, JC-8, JCSP-19, JCSP-3, JCSP-5, JCSP-4	JCSP-9, JC-8, JCSP-19, JCSP-3, JCSP-5, JCSP-4
Sediment PRG	None	None	Scenario 3a = 1st effects benchmark levels Scenario 3b = ½ 1st effects benchmark levels	Scenario 4a = 1st effects benchmark levels Scenario 4b = ½ 1st effects benchmark levels	Scenario 4c = 1st effects benchmark levels Scenario 4d = ½ 1st effects benchmark levels
Soil PRG	None	Background Levels	Background Levels	Background Levels	Background Levels
Dietary Item Input Concentrations	RME Concentrations from collected items at the Site	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME

See notes at end of table.

TABLE 2-2
DESCRIPTION OF REMEDIATION SCENARIOS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Scenario Number	***5a, 5b***	***6a, 6b***	***7a, 7b***
Scenario Description	Remediate top 10 sediment hot spots in Jefferson Canal and Former Star Lake and all of Jefferson Canal Spoil Pile	Remediate all of the "To be addressed in the FS" sediment samples and none of the Jefferson Canal Spoil Pile	Remediate all of the "To be addressed in the FS" sediment samples and all of the Jefferson Canal Spoil Pile
Remediated Sediment Polygons	JC-7, JC-18, SL-7, JC-21, JC-6, JC-13, JC-2, SL-6, JC-3, JC-15	JC-2, JC-3, JC-4, JC-5, JC-6, JC-7, JC-13, JC-14, JC-15, JC-16, JC-17, JC-18, JC-19, JC-20, JC-21, JC-22, JC-23, SLC-9, GSUC-2, GSUC-4, GSUC-5, GSUC-6, GSUC-7, GSUC-8, GSUC-10, JC-1, MB-10, MB-12, MB-13, MB-14, MB-15, MB-16, MB-18, MB-21, MB-23, MB-24, MB-26, MB-28, MB-29, MB-34, MB-42, MB-44, MB-47, MB-48, MB-49, MB-50, MB-51, MB-52 MB-54, MB-55, MB-56, MB-57, MB-58, MB-59, MB-60, MB-61, MB-62, MB-63, SL-1, SL-5, SL-6, SL-7, SL-9, SL-10, SLC-2, SLC-4, SLC-5, SLC-6, SLC-11	JC-2, JC-3, JC-4, JC-5, JC-6, JC-7, JC-13, JC-14, JC-15, JC-16, JC-17, JC-18, JC-19, JC-20, JC-21, JC-22, JC-23, SLC-9, GSUC-2, GSUC-4, GSUC-5, GSUC-6, GSUC-7, GSUC-8, GSUC-10, JC-1, MB-10, MB-12, MB-13, MB-14, MB-15, MB-16, MB-18, MB-21, MB-23, MB-24, MB-26, MB-28, MB-29, MB-34, MB-42, MB-44, MB-47, MB-48, MB-49, MB-50, MB-51, MB-52 MB-54, MB-55, MB-56, MB-57, MB-58, MB-59, MB-60, MB-61, MB-62, MB-63, SL-1, SL-5, SL-6, SL-7, SL-9, SL-10, SLC-2, SLC-4, SLC-5, SLC-6, SLC-11
Remediated Soil Polygons	All	None	All
Sediment PRG	Scenario 5a = 1st effects benchmark levels	Scenario 6a = 1st effects benchmark levels	Scenario 7a = 1st effects benchmark levels
	Scenario 5b = ½ 1st effects benchmark levels	Scenario 6b = ½ 1st effects benchmark levels	Scenario 7b = ½ 1st effects benchmark levels
*Soil **PRG***	Background Levels	None	Background Levels
Dietary Item Input Concentrations	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME

See notes at end of table.

TABLE 2-2
DESCRIPTION OF REMEDIATION SCENARIOS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Scenario Number	***8a, 8b, 8c***	***9a, 9b, 9c***	***10a, 10b, 10c***	***11a, 11b, 11c***
Scenario Description	Remediate all sediment and soil samples at the Site	Remediate all sediment samples with a 3 or 4 ERM-Q/PEL-Q Priority category and none of the Jefferson Canal Spoil Pile	Remediate all sediment samples with a 3 or 4 ERM-Q/PEL-Q Priority category and all of the Jefferson Canal Spoil Pile; Dietary items linked to soil are set to a zero concentration	Remediate all sediment samples with a 3 or 4 ERM-Q/PEL-Q Priority category and all of the Jefferson Canal Spoil Pile
Remediated Sediment Polygons	All	GSUC-7, JC-2, JC-7, JC-13, JC-18, JC-19, MB-10, MB-14, MB-18, MB-21, MB-24, MB-26, MB-49, MB-51, MB-52, MB-54, MB-56, MB-58, MB-59, MB-60, MB-61, MB-62, MB-63, SL-6, SL-7, SL-9, SL-10, SLC-6, SLC-11	GSUC-7, JC-2, JC-7, JC-13, JC-18, JC-19, MB-10, MB-14, MB-18, MB-21, MB-24, MB-26, MB-49, MB-51, MB-52, MB-54, MB-56, MB-58, MB-59, MB-60, MB-61, MB-62, MB-63, SL-6, SL-7, SL-9, SL-10, SLC-6, SLC-11	GSUC-7, JC-2, JC-7, JC-13, JC-18, JC-19, MB-10, MB-14, MB-18, MB-21, MB-24, MB-26, MB-49, MB-51, MB-52, MB-54, MB-56, MB-58, MB-59, MB-60, MB-61, MB-62, MB-63, SL-6, SL-7, SL-9, SL-10, SLC-6, SLC-11
Remediated Soil Polygons	All	None	All	All
Sediment PRG	Scenario 8a = 1st effects benchmark levels	Scenario 9a = 1st effects benchmark levels	Scenario 10a = 1st effects benchmark levels	Scenario 11a = 1st effects benchmark levels
	Scenario 8b = ½ 1st effects benchmark levels	Scenario 9b = ½ 1st effects benchmark levels	Scenario 10b = ½ 1st effects benchmark levels	Scenario 11b = ½ 1st effects benchmark levels
	Scenario 8c = detection limits	Scenario 9c = detection limits	Scenario 10c = detection limits	Scenario 11c = detection limits
Soil PRG	Background Levels	None	Background Levels	Background Levels
Dietary Item Input Concentrations	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by sediment RME for sediment-linked dietary items, Zero concentration for soil-linked dietary items	Site-specific BAF multiplied by media RME

See notes at end of table.

TABLE 2-2
DESCRIPTION OF REMEDIATION SCENARIOS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Scenario Number	***12a, 12b, 12c***	***13a, 13b, 13c***
Scenario Description	Remediate all sediment samples with a 3 or 4 ERM-Q/PEL-Q Priority category with the exception of MB-26, MB-51, MB-58, MB-59, MB-62, MB-63, MB-56; and remediate all of the Jefferson Canal Spoil Pile	Remediate all sediment samples with a 3 or 4 ERM-Q/PEL-Q Priority category with the exception of MB-26, MB-51, MB-58, MB-59; and remediate all of the Jefferson Canal Spoil Pile
Remediated Sediment Polygons	GSUC-7, JC-2, JC-7, JC-13, JC-18, JC-19, MB-10, MB-14, MB-18, MB-21, MB-24, MB-49, MB-52, MB-54, MB-60, MB-61, SL-6, SL-7, SL-9, SL-10, SLC-6, SLC-11	GSUC-7, JC-2, JC-7, JC-13, JC-18, JC-19, MB-10, MB-14, MB-18, MB-21, MB-24, MB-49, MB-52, MB-54, MB-56, MB-60, MB-61, MB-62, MB-63, SL-6, SL-7, SL-9, SL-10, SLC-6, SLC-11
Remediated Soil Polygons	All	All
Sediment PRG	Scenario 12a = 1st effects benchmark levels	Scenario 13a = 1st effects benchmark levels
	Scenario 12b = ½ 1st effects benchmark levels	Scenario 13b = ½ 1st effects benchmark levels
	Scenario 12c = detection limits	Scenario 13c = detection limits
Soil PRG	Background Levels	Background Levels
Dietary Item Input Concentrations	Site-specific BAF multiplied by media RME	Site-specific BAF multiplied by media RME

Notes:
PRG = Preliminary remediation goal
BAF = Bioaccumulation factor
RME = Reasonable Maximum Exposure
FS = Feasibility Study
Hot spots identified by the Total PCL Exceedance Ratios
PRGs are provided in Tables 3-4A and 3-4B
ERM-Q/PEL-Q = Effects Range Median Quotient/Probable Effects Level Quotient

JC = Jefferson Canal
JCSP = Jefferson Canal Spoil Pile
SL = Former Star Lake
SLC = Star Lake Canal
GSUC = Gulf States Utility Canal
MB = Molasses Bayou

TABLE 2-3
REFINEMENT OF COPEC LIST FOR SENSITIVITY ANALYSIS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

COPECs	*Removed from Sensitivity Analysis?*
Carbon Disulfide	Retained
Ethylbenzene	Retained
Benzaldehyde	Removed
Dibenzofuran	Retained
Hexachlorobenzene	Removed
Nitrobenzene	Removed
Pentachlorophenol	Retained
Total PAHs	Retained
Total Toxicity Equivalents of PCB Congeners	Removed
Endosulfan II	Retained
Endrin	Removed
Aluminum	Retained
Antimony	Retained
Arsenic	Retained
Cadmium	Retained
Chromium Total	Retained
Chromium VI	Retained
Copper	Retained
Lead	Retained
Manganese	Retained
Selenium	Retained
Vanadium	Retained
Zinc	Removed

Notes:
COPEC = Constituent of Potential Ecological Concern
HQ = Hazard Quotient
NOAEL = No Observed Adverse Effect Level
GMATC = Geometric Mean Acceptable Toxicant Concentration
COPECs removed if the GMACT HQ < 1 for all receptors and the NOAEL HQ < 1 for threatened and endangered species.

TABLE 2-4
REMEDIATION CONCENTRATIONS USED IN SENSITIVITY ANALYSIS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituent	*First Effects Level Benchmarks*		*One-half First Effects Level Benchmarks*		*Detection Limits*		*Background Level*
	Freshwater Sediment	*Saltwater Sediment*	*Freshwater Sediment*	*Saltwater Sediment*	*Freshwater Sediment*	*Saltwater Sediment*	*Soil*
Carbon disulfide	0.12	0.12[6]	0.06	0.06[6]	0.00005	0.00005	0.0941[2]
Ethylbenzene	2.86	0.65	1.43	0.325	0.00006	0.00006	0.03[2]
Dibenzofuran	0.63	7.3[1]	0.315	3.5[1]	0.0053	0.0053	0.00995[8]
Pentachlorophenol	0.504	7.97	0.25	3.99	0.13	0.13	5[4]
Total PAHs	1.61	4.022	0.81	2.01	0.001	0.001	1[2]
Endosulfan II	0.014[5]	0.014[5,6]	0.007[5]	0.007[5,6]	0.00033	0.00033	0.00001[2]
Aluminum	25500[1]	18000[1]	12750[1]	9000[1]	6.05	6.05	30000
Antimony	2	0.150[2]	1	0.075[2]	0.66	0.66	1
Arsenic	9.79	8.2	4.895	4.1	0.55	0.55	5.9
Cadmium	0.99	1.2	0.495	0.6	0.02	0.02	32[4]
Chromium Total	43.4[7]	81	21.7[7]	40.5	0.14	0.14	30
Chromium VI	5.427[8]	0.5[8]	2.71[8]	0.25[8]	0.5	0.5	37[2]
Copper	31.6	34	15.8	17	0.096	0.096	15
Lead	35.8	46.7	17.9	23.4	0.22	0.22	15
Manganese	460	260[1]	230	130[1]	0.036	0.036	300
Selenium	0.29[2,3]	1.0[2]	0.15[2,3]	0.5[2]	0.68	0.68	0.3
Vanadium	50[2,3]	57[2]	25[2,3]	28.5[2]	0.14	0.14	50

Notes:

All concentrations are reported as mg/kg dry weight.

Freshwater and saltwater remediation concentrations from first effects level benchmarks in Table 3-3 in TCEQ TRRP RG-263, Revised 2006, unless otherwise noted

Soil remediation concentrations selected from Texas median background concentrations in Table 3-4 in TCEQ TRRP RG-263, Revised 2006, unless otherwise noted

(1) Sediment screening benchmark obtained from USEPA, Region 3

(2) Buchman, M.F., 2008. NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle, WA, Office of Response and Restoration Division, National Oceanographic and Atmospheric Administration, 34 pages

(3) Background concentration reported in NOAA Screening Quick Reference Tables

(4) Soil ecological benchmark selected from Table 3-4 in TCEQ TRRP RG-263, Revised 2006

(5) EPA Region 3 BTAG Screening Benchmarks. http://www.epa.gov/reg3hwmd/risk/eco/index.htm

(6) Freshwater sediment benchmark used for saltwater due to unavailablility of saltwater benchmark

(7) Chromium total benchmark for freshwater using hardness of 100

(8) Lowest detected concentration found at the Site used due to unavailability of benchmark

TABLE 2-5
PERCENTAGE OF HAZARD QUOTIENTS DROPPING BELOW ONE
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Remediation Scenario	*Percentage of HQ< 1*	*Total Remediated Acres (in Scenario)*
Scenario 1	0.00	0.00
Scenario 2	7.35	10.62
Scenario 3a	17.65	10.42
Scenario 3b	17.65	10.42
Scenario 4a	19.12	6.17
Scenario 4b	20.59	6.17
Scenario 4c	20.59	14.98
Scenario 4d	22.06	14.98
Scenario 5a	27.94	15.08
Scenario 5b	29.41	15.08
Scenario 6a	22.06	169.13
Scenario 6b	26.47	169.13
Scenario 7a	35.29	179.75
Scenario 7b	39.71	179.75
Scenario 8a	36.76	386.51
Scenario 8b	51.47	386.51
Scenario 8c	67.60	386.51
Scenario 9a	20.59	45.69
Scenario 9b	22.06	45.69
Scenario 9c	13.24	45.69
Scenario 10a	67.65	56.31
Scenario 10b	72.06	56.31
Scenario 10c	58.82	56.31
Scenario 11a	35.29	56.31
Scenario 11b	39.71	56.31
Scenario 11c	25.00	56.31
Scenario 12a	33.82	25.40
Scenario 12b	38.24	25.40
Scenario 12c	22.06	25.40
Scenario 13a	29.41	36.62
Scenario 13b	39.71	36.62
Scenario 13c	23.53	36.62

Notes:

The total Hazard Quotient (HQ) number reflects the total number of HQs reported as greater than one in the Tier 2 Remedial Investigation.

TABLE 2-6
SUMMARY OF HAZARD QUOTIENTS WITHIN EACH REMEDIATION SCENARIO
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Remediation Scenario	*Number of HQ < 1*	*Number of HQ ≥ 1 and < 10*	*Number of HQ ≥ 10*
Scenario 1	0	53	15
Scenario 2	5	47	16
Scenario 3a	12	39	17
Scenario 3b	12	39	17
Scenario 4a	13	38	17
Scenario 4b	14	38	16
Scenario 4c	14	37	17
Scenario 4d	15	36	17
Scenario 5a	19	38	11
Scenario 5b	20	37	11
Scenario 6a	15	34	19
Scenario 6b	18	32	18
Scenario 7a	24	36	8
Scenario 7b	27	33	8
Scenario 8a	25	34	9
Scenario 8b	35	26	7
Scenario 8c	46	21	1
Scenario 9a	14	36	18
Scenario 9b	15	33	20
Scenario 9c	9	38	21
Scenario 10a	46	19	3
Scenario 10b	49	16	3
Scenario 10c	40	25	3
Scenario 11a	24	36	8
Scenario 11b	27	32	9
Scenario 11c	17	41	10
Scenario 12a	23	35	10
Scenario 12b	26	32	10
Scenario 12c	15	41	12
Scenario 13a	20	38	10
Scenario 13b	27	31	10
Scenario 13c	16	41	11

Notes:

The total Hazard Quotient (HQ) number reflects the total number of HQs reported as greater than one in the Tier 2 Remedial Investigation.

TABLE 2-7
HAZARD QUOTIENT RESULTS FOR SCENARIO 10B
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituents	*Raccoon*			*Muskrat*			*Short-tailed shrew*			*American robin*			*Belted kingfisher*			*Mallard*		
	LOAEL	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*
Carbon Disulfide	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Ethylbenzene	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Dibenzofuran	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Pentachlorophenol	7.04E-01	**1.57E+00**	**3.52E+00**	NN	NN	NN	1.28E-04	2.85E-04	6.38E-04	NN	NN	NN	NN	NN	NN	NN	NN	NN
Total PAHs	NN	NN	**1.04E+00**	NN	NN	**3.75E+00**	4.09E-03	9.04E-03	2.00E-02	NN	NN	NN	NN	NN	NN	NN	NN	NN
Endosulfan II	NN	9.86E-01	**2.20E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Aluminum	2.43E-01	5.43E-01	**1.21E+00**	NN	8.57E-01	**1.92E+00**	4.98E-01	**1.11E+00**	**2.49E+00**	**1.36E+00**	**3.04E+00**	**6.79E+00**	**1.47E+01**	**3.28E+01**	**7.33E+01**	NN	NN	6.17E-01
Antimony	NN	NN	NN	NN	NN	NN	NN	NN	5.75E-03	2.76E-03	6.18E-03	1.38E-02	3.61E-01	8.08E-01	**1.81E+00**	NN	NN	-
Arsenic	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Cadmium	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	9.28E-04	2.07E-03	NN	NN	**1.77E+00**	NN	NN	NN
Chromium Total	NN	NN	NN	NN	NN	NN	NN	NN	NN	2.07E-03	4.63E-03	1.04E-02	NN	NN	6.27E-01	NN	NN	NN
Chromium VI	NN	2.47E-01	5.53E-01	3.38E-01	7.55E-01	**1.69E+00**	NN	NN	NN	3.12E-03	6.97E-03	1.56E-02	NN	**4.23E+00**	**9.47E+00**	NN	NN	NN
Copper	NN	NN	NN	NN	NN	NN	NN	NN	NN	1.55E-03	3.47E-03	7.75E-03	6.22E-01	**1.39E+00**	**3.11E+00**	NN	NN	NN
Lead	NN	NN	4.70E-02	NN	NN	NN	5.39E-03	1.21E-02	2.70E-02	9.38E-04	2.10E-03	4.69E-03	NN	NN	NN	NN	NN	NN
Manganese	3.55E-01	7.94E-01	**1.78E+00**	**1.33E+00**	**2.97E+00**	**6.64E+00**	NN	NN	NN	2.87E-03	6.41E-03	1.43E-02	NN	**1.49E+00**	**3.34E+00**	NN	NN	NN
Selenium	3.37E-01	7.54E-01	**1.69E+00**	1.83E-01	4.09E-01	9.15E-01	3.03E-03	6.77E-03	1.51E-02	NN	1.45E-03	3.25E-03	NN	NN	3.62E-01	NN	NN	NN
Vanadium	8.88E-02	1.98E-01	4.44E-01	NN	NN	8.03E-01	5.67E-02	8.02E-02	1.13E-01	8.91E-03	1.99E-02	4.46E-02	NN	NN	8.59E-01	NN	NN	NN

TABLE 2-7
HAZARD QUOTIENT RESULTS FOR SCENARIO 10B
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituents	*Marsh wren*			*Spotted sandpiper*			*White-faced ibis*			*Wood stork*			*Bullfrog*			*Painted turtle*		
	LOAEL	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*
Carbon Disulfide	NN	NN	NN	NN	2.69E-02	6.01E-02	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Ethylbenzene	NN	7.19E-04	1.61E-03	NN	NN	**3.91E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Dibenzofuran	NN	NN	NN	2.39E-01	5.36E-01	**1.20E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Pentachlorophenol	NN	NN	NN	NN	NN	**3.94E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	**2.10E+00**
Total PAHs	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Endosulfan II	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Aluminum	**5.10E+00**	**1.14E+01**	**2.55E+01**	**1.30E+01**	**2.91E+01**	**6.52E+01**	2.92E-02	6.54E-02	1.46E-01	NN	NN	**1.51E+00**	NN	**1.54E+00**	**3.44E+00**	NN	5.73E-01	**1.28E+00**
Antimony	7.72E-03	1.73E-02	3.86E-02	1.10E-01	2.47E-01	5.52E-01	NN	NN	1.26E-01	NN	NN	3.93E-01	NN	3.53E-01	7.90E-01	NN	NN	2.78E-01
Arsenic	NN	NN	1.22E-03	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	9.43E-01	**2.11E+00**	NN	NN	7.32E-01
Cadmium	NN	5.32E-03	1.19E-02	NN	2.34E-01	5.24E-01	NN	NN	NN	NN	NN	NN	NN	NN	**3.02E+00**	NN	NN	NN
Chromium Total	NN	NN	NN	NN	NN	2.82E-01	NN	NN	NN	NN	NN	NN	NN	NN	4.44E-01	NN	NN	NN
Chromium VI	7.21E-03	1.61E-02	3.60E-02	4.50E-01	**1.01E+00**	**2.25E+00**	NN	NN	NN	NN	NN	NN	NN	**2.69E+00**	**6.02E+00**	NN	NN	**1.04E+00**
Copper	3.92E-02	8.77E-02	1.96E-01	6.22E-01	**1.39E+00**	**3.11E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Lead	NN	NN	NN	NN	8.17E-02	1.83E-01	NN	NN	3.75E-02	NN	NN	NN	NN	7.02E-01	**1.57E+00**	NN	NN	NN
Manganese	NN	4.09E-02	9.14E-02	NN	9.85E-01	**2.20E+00**	NN	NN	NN	NN	NN	NN	4.29E-02	9.60E-02	2.15E-01	**1.60E+00**	**3.58E+00**	**8.02E+00**
Selenium	NN	6.14E-03	1.37E-02	NN	5.15E-02	1.15E-01	NN	NN	NN	NN	NN	NN	NN	NN	3.25E-01	NN	NN	NN
Vanadium	NN	NN	NN	NN	2.56E-01	5.72E-01	NN	NN	NN	NN	NN	NN	NN	NN	**1.23E+00**	NN	NN	NN

Notes:

Scenario 10b = Remediate all sediment samples with an Effects Range Median-Quotient/Probable Effects Level-Quotient (ERM-Q/PEL-Q) Score > 2 to ½ 1st effects benchmark levels, all soil to background levels, and all earthworms, terrestrial plants and insects set to a zero concentration.

Bold values indicate a Hazard Quotient (HQ) >1

NN = Not Needed - indicates risk was acceptable at the Site, therefore evaluation in the Sensitivity Analysis was not necessary

NOAEL = No Observed Adverse Effects Level

LOAEL = Low Observed Adverse Effects Level

GMATC = Geometric Maximum Allowable Toxicant Concentration

TABLE 2-8
HAZARD QUOTIENT RESULTS FOR SCENARIO 10B AFTER RISK ANALYSIS MODIFICATIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituents	*Raccoon*			*Muskrat*			*Short-tailed shrew*			*American robin*			*Belted kingfisher*			*Mallard*		
	LOAEL	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*
Carbon Disulfide	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Ethylbenzene	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Dibenzofuran	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Pentachlorophenol	7.04E-01	**1.57E+00**	**3.52E+00**	NN	NN	NN	1.28E-04	2.85E-04	6.38E-04	NN	NN	NN	NN	NN	NN	NN	NN	NN
Total PAHs	NN	NN	**1.04E+00**	NN	NN	**3.75E+00**	4.09E-03	9.04E-03	2.00E-02	NN	NN	NN	NN	NN	NN	NN	NN	NN
Endosulfan II	NN	9.86E-01	**2.20E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Aluminum	2.43E-01	5.43E-01	**1.21E+00**	NN	8.57E-01	**1.92E+00**	4.98E-01	**1.11E+00**	**2.49E+00**	**1.36E+00**	**3.04E+00**	**6.79E+00**	**1.47E+01**	**3.28E+01**	**7.33E+01**	NN	NN	6.17E-01
Antimony	NN	NN	NN	NN	NN	NN	NN	NN	5.75E-03	2.76E-03	6.18E-03	1.38E-02	3.61E-01	8.08E-01	**1.81E+00**	NN	NN	NN
Arsenic	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Cadmium	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	9.28E-04	2.07E-03	NN	NN	**1.77E+00**	NN	NN	NN
Chromium Total	NN	NN	NN	NN	NN	NN	NN	NN	NN	2.07E-03	4.63E-03	1.04E-02	NN	NN	6.27E-01	NN	NN	NN
Chromium VI	NN	2.47E-01	5.53E-01	3.38E-01	7.55E-01	**1.69E+00**	NN	NN	NN	3.12E-03	6.97E-03	1.56E-02	NN	*8.51E-01*	***1.90E+00***	NN	NN	NN
Copper	NN	NN	NN	NN	NN	NN	NN	NN	NN	1.55E-03	3.47E-03	7.75E-03	6.22E-01	**1.39E+00**	**3.11E+00**	NN	NN	NN
Lead	NN	NN	4.70E-02	NN	NN	NN	5.39E-03	1.21E-02	2.70E-02	9.38E-04	2.10E-03	4.69E-03	NN	NN	NN	NN	NN	NN
Manganese	3.55E-01	7.94E-01	**1.78E+00**	*2.27E-01*	*5.08E-01*	***1.14E+00***	NN	NN	NN	2.87E-03	6.41E-03	1.43E-02	NN	*6.10E-02*	*1.36E-01*	NN	NN	NN
Selenium	3.37E-01	7.54E-01	**1.69E+00**	1.83E-01	4.09E-01	9.15E-01	3.03E-03	6.77E-03	1.51E-02	NN	1.45E-03	3.25E-03	NN	NN	3.62E-01	NN	NN	NN
Vanadium	8.88E-02	1.98E-01	4.44E-01	NN	NN	8.03E-01	5.67E-02	8.02E-02	1.13E-01	8.91E-03	1.99E-02	4.46E-02	NN	NN	8.59E-01	NN	NN	NN

TABLE 2-8
HAZARD QUOTIENT RESULTS FOR SCENARIO 10B AFTER RISK ANALYSIS MODIFICATIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituents	*Marsh wren*			*Spotted sandpiper*			*White-faced ibis*			*Wood stork*			*Bullfrog*			*Painted turtle*		
	LOAEL	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*	*LOAEL*	*GMATC*	*NOAEL*
Carbon Disulfide	NN	NN	NN	NN	2.69E-02	6.01E-02	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Ethylbenzene	NN	7.19E-04	1.61E-03	NN	-	**3.91E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Dibenzofuran	NN	NN	NN	2.39E-01	5.36E-01	**1.20E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Pentachlorophenol	NN	NN	NN	NN	NN	**3.94E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	*5.70E-02*
Total PAHs	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Endosulfan II	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Aluminum	**5.10E+00**	**1.14E+01**	**2.55E+01**	**1.30E+01**	**2.91E+01**	**6.52E+01**	2.92E-02	6.54E-02	1.46E-01	NN	NN	**1.51E+00**	NN	**1.54E+00**	**3.44E+00**	NN	***1.25E+00***	***2.79E+00***
Antimony	7.72E-03	1.73E-02	3.86E-02	1.10E-01	2.47E-01	5.52E-01	NN	NN	1.26E-01	NN	NN	3.93E-01	NN	3.53E-01	7.90E-01	NN	NN	3.28E-01
Arsenic	NN	NN	1.22E-03	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	9.43E-01	**2.11E+00**	NN	NN	8.87E-01
Cadmium	NN	5.32E-03	1.19E-02	NN	2.34E-01	5.24E-01	NN	NN	NN	NN	NN	NN	NN	NN	**3.02E+00**	NN	NN	NN
Chromium Total	NN	NN	NN	NN	NN	2.82E-01	NN	NN	NN	NN	NN	NN	NN	NN	4.44E-01	NN	NN	NN
Chromium VI	7.21E-03	1.61E-02	3.60E-02	*4.39E-01*	*9.81E-01*	***2.19E+00***	NN	NN	NN	NN	NN	NN	NN	*6.37E-01*	**1.42E+00**	NN	NN	6.18E-01
Copper	3.92E-02	8.77E-02	1.96E-01	6.22E-01	**1.39E+00**	**3.11E+00**	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Lead	NN	NN	NN	NN	8.17E-02	1.83E-01	NN	NN	3.75E-02	NN	NN	NN	NN	7.02E-01	**1.57E+00**	NN	NN	NN
Manganese	NN	4.09E-02	9.14E-02	NN	9.85E-01	**2.20E+00**	NN	NN	NN	NN	NN	NN	4.29E-02	9.60E-02	2.15E-01	*1.52E-01*	*3.41E-01*	*7.62E-01*
Selenium	NN	6.14E-03	1.37E-02	NN	5.15E-02	1.15E-01	NN	NN	NN	NN	NN	NN	NN	NN	3.25E-01	NN	NN	NN
Vanadium	NN	NN	NN	NN	2.56E-01	5.72E-01	NN	NN	NN	NN	NN	NN	NN	NN	**1.23E+00**	NN	NN	NN

Notes:

Scenario 10b = Remediate all sediment samples with an Effects Range Median-Quotient/Probable Effects Level-Quotient (ERM-Q/PEL-Q) Score > 2 to ½ 1st effects benchmark levels, all soil to background levels, and all earthworms, terrestrial plants and insects set to a zero concentration.

Italicized values indicate the modified risk evaluations

Bold values indicate a Hazard Quotient (HQ) >1

NN = Not Needed - indicates risk was acceptable at the Site, therefore evaluation in the Sensitivity Analysis was not necessary

NOAEL = No Observed Adverse Effects Level

LOAEL = Low Observed Adverse Effects Level

GMATC = Geometric Maximum Allowable Toxicant Concentration

TABLE 3-1
CHEMICAL-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Statutes	***ARARs (Regulations)***	***Summary of Topics within Cited Regulations***	***Reason for retention or elimination***
Texas Commission on Environmental Quality	TAC Title 30 Part 1 Chapters 307, 308, 314, 327, 335, and 350	General surface water quality standards; implementation of remedial technologies; effluent discharge standards; release to the environment; handling and disposal of hazardous waste; procedures for compliance with Texas Risk Reduction Program for the protection of ecological receptors	Applicable to environmental remediation activities in the state of Texas
Toxic Substances Control Act (TSCA)	40 CFR 761	Disposal of Polychlorinated Biphenyls (PCBs)	Applicable for PCB disposal for water, soil, and sediment.
Clean Water Act (CWA)	Section 404 National Pollutant Discharge Elimination System (NPDES)	Dredging, backfill, or infill materials or activities within waters and wetlands of the United States.	Applicable for waters of the United States.
Safe Drinking Water Act (SDWA)	Not Applicable	Protect public health by regulating the nation's public drinking water supply and its sources: rivers, lakes, reservoirs, springs, and groundwater wells.	None - not applicable to remediation activities; groundwater intrusion to drinking wells eliminated in Tier 2 Remedial Investigation Report.
Clean Air Act (CAA)	40 CFR 50-99	Comprehensive federal law that regulates air emissions from area, stationary, and mobile sources to protect public health and the environment.	None - not applicable to constituents of concern (COCs) that volatilize from soil or from dust generated by remediation activities including excavation, transportation and disposal.

TABLE 3-2
LOCATION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Potentially Applicable Statutes	***ARARs (Regulations)***	***Summary of Topics within Cited Regulations***	***Reason for retention or elimination***
Clean Water Act (CWA)	Section 404 National Pollutant Discharge Elimination System (NPDES)	Dredging, backfill, or infill materials or activities within waters and wetlands of the United States.	Applicable for waters of the United States.
Floodplain Management	40 CFR Part 6 Appendix A and 40 CFR 6.302	Applicable if remedial activities occur in the floodplain	Applicable to activities taking place within a documented floodplain.
Protection of Wetlands	40 CFR Section 6.302 (a)	Applicable if remedial activities affect or impact wetlands	Applicable to activities taking place in delineated wetlands.
National Historical Preservation Act	16 USC Section 470 & 661 et seq., 36 CFR Part 65, 36 CFR Part 800	Defines procedures to preserve scientific, historical, and archaeological data from potential destruction resulting from a change in the site terrain resulting from a federal construction project or federally licensed activity. If such artifacts are discovered during work at the site, work in the area will be stopped until data recovery and preservation activities are completed in accordance with the Act and regulations.	Applicable if scientific, historical, and archaeological data is discovered during project.
Endangered Species Act of 1973	16 USC Section 1531 et seq., 50 CFR 222-228	Federal agencies must confirm any action that is federally authorized, funded, or implemented by the agency is not probable to adversely effect the continued existence of any threatened or endangered species. The agency must ensure that the critical habitat is not destroyed or negatively modified.	Applicable if threatened or endangered species are found on-site.
Rivers and Harbors Act of 1899	Section 10 (33 USC Section 401 et. seq.), 33 CFR 322	Approval from the U.S. Army Corps of Engineers is generally required when altering the course, location, condition, or capacity of the channel of any navigable water of the United States by excavating or filling.	Applicable for areas that excavation and capping are proposed.
Fish and Wildlife Coordination Act	16 U.S.C. Section 662	When modifications to a stream or other water body are proposed or approved by any United States agency, such agency shall review with the United States Fish and Wildlife Service, Department of the Interior, and with the head of the agency overseeing the wildlife resources of the Site.	Applicable for areas that excavation and capping are proposed.

TABLE 3-3
ACTION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Potentially Applicable Statutes	***ARARs (Regulations)***	***Summary of Topics within Cited Regulations***	***Reason for retention or elimination***
Resource Conservation and Recovery Act (RCRA)	40 CFR 260, 261, 262, 263, 264, 268, 270, 271, 272, 370	General Hazardous Waste Management including identification, generation, transportation, disposal of waste; Permitting, monitoring, and reporting requirements; authorization and recognition of Sate Hazardous Waste Programs; chemical release reporting	Applicable for transportation and disposal of hazardous waste as defined by RCRA (listed or based on characteristics).
Toxic Substances Control Act (TSCA)	40 CFR 761	Disposal of polychlorinated biphenyls (PCBs)	Applicable disposal for water, soil, and sediment impacted by PCBs.
Clean Water Act (CWA)	Section 404 National Pollutant Discharge Elimination System (NPDES)	Dredging, backfill, or infill materials or activities within waters and wetlands of the United States.	Applicable for waters of the United States.
Clean Air Act (CAA)	40 CFR 50-99	Comprehensive federal law that regulates air emissions from area, stationary, and mobile sources to protect public health and the environment.	None- not applicable to constituents of concern (COCs) that volatilize from soil or from dust generated by remediation activities including excavation, transportation and disposal.
Occupational Safety and Health Administration (OSHA)	Sections 5, 6,8, 13,17, 21, 26, and 27	Duties of the employer regarding safe workplace; OSHA Standards; Safety and Health inspections, investigations and record keeping; procedures to counteract imminent; penalties of non-compliance; training and employee education; annual reporting requirements; worker's compensation.	Applies to all Site workers
Hazardous Material Transportation Act	49 CFR 107, 171-177	Regulates transportation of hazardous materials.	Applies to off-Site disposal activities of soil and sediment considered hazardous materials as defined in Section 172.101.

TABLE 3-4A
PRELIMINARY REMEDIATION GOALS - SEDIMENT
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituent of Potential Ecological Concern (COPEC)	*Upper Trophic Level Sediment PRG*		*Benthic Invertebrate Sediment PRG*		*Ecological Sediment PRG [1]*	
	Freshwater	*Saltwater*	*Freshwater*	*Saltwater*	*Freshwater*	*Saltwater*
Metals						
Antimony	1	0.075[2]	No Risk	No Risk	1	0.075[2]
Arsenic	4.895	4.1	9.79	8.2	4.895	4.1
Cadmium	0.495	0.6	0.99	1.2	0.495	0.6
Chromium	21.7[7]	40.5	43.4	81	21.7[7]	40.5
Chromium VI	2.71[8]	0.25[8]	No Risk	No Risk	2.71[8]	0.25[8]
Copper	15.8	17	31.6	34	15.8	17
Lead	17.9	23.4	35.8	46.7	17.9	23.4
Manganese	230	130[1]	No Risk	No Risk	230	130[1]
Mercury	No Risk	No Risk	0.18	0.15	0.18	0.15
Selenium	0.15[2,3]	0.5[2]	No Risk	No Risk	0.15[2,3]	0.5[2]
Silver	No Risk	No Risk	1	1	1	1
Vanadium	25[2,3]	28.5[2]	No Risk	No Risk	25[2,3]	28.5[2]
Zinc	No Risk	No Risk	121	150	121	150
Semi-Volatile Organic Compounds (SVOCs)						
Dibenzofuran	0.315	3.5[1]	No Risk	No Risk	0.315	3.5[1]
Pesticides						
4,4'-DDE	No Risk	No Risk	0.00316	0.00207	0.00316	0.00207
4,4'-DDT	No Risk	No Risk	0.00416	0.00119	0.00416	0.00119
Dieldrin	No Risk	No Risk	0.0019	0.000715	0.0019	0.000715
Endosulfan II	0.007[5]	0.007[5,6]	No Risk	No Risk	0.007[5]	0.007[5,6]
Pentachlorophenol	0.25	3.99	No Risk	No Risk	0.25	3.99
Volatile Organic Compounds (VOCs)						
Carbon disulfide	0.06	0.06[6]	No Risk	No Risk	0.06	0.06[6]
Ethylbenzene	1.43	0.325	No Risk	No Risk	1.43	0.325
Polycyclic Aromatic Hydrocarbons (PAHs)						
Total PAH	0.81	2.01	1.61	4.022	0.81	2.01
Polychlorinated Biphenyls (PCBs)						
Total PCBs (Aroclors)	No Risk	No Risk	0.0598	0.0227	0.0598	0.0227

Notes:

PRG = Preliminary Remediation Goal

All concentrations are reported as mg/kg dry weight.

Freshwater and saltwater upper trophic level PRGs are one-half of the first effects level benchmarks in Table 3-3 in TCEQ TRRP RG-263, Revised 2006, unless otherwise noted

(1)Ecological Sediment PRG determined as the lower concentration of the upper trophic level and benthic invertebrate sediment PRGs and are the final PRGs to be used as a clean-up goal

(2)Sediment screening benchmark obtained from USEPA, Region 3

(3)Buchman, M.F., 2008. NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle, WA, Office of Response and Restoration Division, National Oceanographic and Atmospheric Administration, 34 pages

(4)Background concentration reported in NOAA Screening Quick Reference Tables

(5)EPA Region 3 BTAG Screening Benchmarks. http://www.epa.gov/reg3hwmd/risk/eco/index.htm

(6)Freshwater sediment benchmark used for saltwater due to unavailability of saltwater benchmark

(7)Chromium total benchmark for freshwater using hardness of 100

(8)Lowest detected concentration found at the Site used due to unavailability of benchmark

TABLE 3-4B
PRELIMINARY REMEDIATION GOALS - SOIL
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Constituent of Potential Ecological Concern (COPEC)	*Upper Trophic Level PRG*	*Ecological PRG (1)*
Metals		
Antimony	1	1
Arsenic	5.9	5.9
Cadmium	32 (4)	32 (4)
Chromium	30	30
Chromium VI	37 (2)	37 (2)
Copper	15	15
Lead	15	15
Manganese	300	300
Selenium	0.3	0.3
Vanadium	50	50
Polycyclic Aromatic Hydrocarbons (PAHs)		
Total PAH	1 (2)	1 (2)
Volatile Organic Compounds (VOCs)		
Carbon disulfide	0.0941 (2)	0.0941 (2)
Ethylbenzene	0.03 (2)	0.03 (2)
Semi-Volatile Organic Compounds (SVOCs)		
Dibenzofuran	0.009954 (3)	0.009954 (3)
Pesticides		
Pentachlorophenol	5 (4)	5 (4)
Endosulfan II	0.00001 (2)	0.00001 (2)

Notes:

PRG = Preliminary Remediation Goal

COPEC = Constituent of Potential Ecological Concern

All values are in mg/kg dry weight.

Soil PRGs selected from Texas median background concentrations in Table 3-4 in TCEQ TRRP RG-263, Revised 2006, unless otherwise noted.

(1) Ecological PRGs are the final PRGs to be used as a clean-up goal

(2) Buchman, M.F., 2008. NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle, WA, Office of Respons e and Restoration Division, National Oceanographic and Atmospheric Administration, 34 pages.

(3) Lowest detected concentration at the Site used due to unavailability of benchmark.

(4) PRGs used from Table 3-4 in TCEQ TRRP RG-263 for plants.

TABLE 3-5
GENERAL RESPONSE ACTIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	*Description/Examples*
No Action	"No Action" is a baseline and used to evaluate other remediation technologies. The Site represents existing conditions since remediation is not implemented.
Institutional Controls	Institutional controls are administrative or legal controls and may include deed restrictions, easements, covenants: tools based on property law to prohibit or control activities on the property, seafood consumption health advisories, public outreach, and education. Government controls such as zoning restrictions, ordinances and permits that restrict land and waterway use (ex: no-dredging areas or no-anchoring areas) are institutional controls. Constraints, such as fencing and signs, to inhibit property access are additional examples of institutional controls.
Monitored Natural Recovery	MNR allows impacted soil or sediment to remain in place. Natural processes (chemical, physical, or biological) occur that contain, reduce, eliminate, or modify the constituents of concern in sediment or soil. Long-term monitoring may be required for MNR. Sorption, desorption, dispersion, diffusion, dilution, volatilization, resuspension, and transport are processes that influence recovery. Metabolism by microorganisms occurs in aerobic and anaerobic environments. This metabolism may dechlorinate polychorinated biphenyls (PCBs) and pesticides and partially or completely degrade polycyclic aromatic hydrocarbons (PAHs), semi-volatile organic compounds (SVOCs), and volatile organic compounds (VOCs). Impacted sediments are buried through sedimentation. Deeper sediments become less bioavailable as sedimentation occurs.
Enhanced Natural Recovery	ENR includes the application of a thin layer of clean material or a thin layer of clean material with amendments. Clean material overlying impaired sediments allows natural bioturbation and benthic recolonization. Amendments such as granulated activated carbon or iron filings may be included in the clean material cap to provide sites for chemical binding of constituents of concern (COCs) when they migrate into sediment pore water. ENR may require long term monitoring.
Containment	Containment includes the installation of a cap over the impacted sediment or soil to isolate the impact. Cap types include conventional sand cap, conventional sediment or clay cap, armored cap, composite cap, spray cap, or reactive cap. Long-term monitoring will be required to confirm the cap performance.
Removal	This action involves removing the impacted sediment by dredging or excavation. Once removed, the sediment may be treated and disposed off-site. Sediment removal is influenced by various site characteristics including water depth, extent of impact, and site location.
In Situ Treatment	In Situ treatment utilizes specific processes to treat the sediment in place. Chemical, physical, or biological processes are used to isolate or reduce constituent concentrations in the impacted sediment.
Ex Situ Treatment	Ex Situ treatments may occur either on-site or off-site using thermal, biological, physical, or chemical processes. After the sediment is treated, the sediment may be beneficially used or disposed at less costs than untreated sediment.
Disposal	Sediments are taken off-site to a landfill, used for a beneficial purpose after treatment, or confined to an isolated area on-site.

TABLE 3-6
POTENTIAL TECHNOLOGY TYPES AND PROCESS OPTIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	*Technology type*	*Process Option*	*Description of Process Option*
No action	None	Not applicable	No action
Institutional controls	Non-engineered actions intended to reduce human exposure to sediments	Proprietary controls	Deed restrictions, easements, or covenants: tools based on property law to prohibit or control activities on the property
		Informational devices	Seafood consumption health advisories, public outreach, and education
		Enforcement tools	Government controls such as zoning restrictions, ordinances and permits that restrict land and waterway use (ex: no-dredging areas or no-anchoring areas)
		Site registry	Some states have a hazardous site registry that provides information on site-related property restrictions.
	Engineered actions intended to reduce human exposure to sediments	Access restrictions	Constraints, such as fencing and signs, to inhibit property access
Monitored natural recovery	Chemical/physical transport and degradation	Combined	Sorption, desorption, dispersion, diffusion, dilution, volatilization, resuspension, and transport
	Biological degradation	Metabolism of COCs by microorganisms	Metabolism by microorganisms occurs in aerobic and anaerobic environments. Polychlorinated biphenyls (PCBs) and pesticides may be dechlorinated; polycyclic aromatic hydrocarbons (PAHs), semi-volatile organic compounds (SVOCs), and volatile organic compounds (VOCs) may be partially or completely degraded.
	Physical burial processes	Burial by sedimentation and deposition	Sedimentation and/or deposition bury impaired sediments by natural processes. Deeper sediments become less bioavailable.
Enhanced natural recovery	Thin-layer placement	Application of a thin layer of clean material	Clean material overlying impaired sediments allows natural bioturbation and benthic recolonization. Mixing achieves acceptable COC concentrations.
	Enhanced thin layer cap	Application of a thin layer of clean material with amendments	Materials such as granulated activated carbon or iron filings are included in the clean material cap to provide sites for chemical binding of COCs when they migrate into sediment pore water.
Containment	*In Situ* capping	Conventional sand cap	Clean sand is placed over sediment to isolate impact and create a new benthic habitat.
		Conventional sediment or clay cap	Fine grained sediments or clays are placed over impaired sediment to isolate COCs.
		Armored cap	Cobbles, pebbles, or larger material is placed over sediment to prohibit bioturbation by burrowing organisms and to stabilize and prevent erosion or cap breaching.
		Composite cap	Soil, media, and geotextile (synthetic fabric for stability) cap is placed over sediments to inhibit migration of impaired pore water and to inhibit bioturbators.
		Spray cap	Concrete or mortar is sprayed at high velocity over sediment surface in either a wet or dry process.
		Reactive cap	Cap contains amendment materials such as activated carbon or apatite that inhibit mobilization of COCs via chemical binding.
Removal	Dredging	Hydraulic dredging	Sediment is loosened with a cutter head, bucket wheel, dustpan, auger, or hopper dredge. A pump provides suction to hydraulically move the sediment through a pipeline to a land location.
		Mechanical dredging	A dredging bucket extracts the sediment and raises it to the surface to be deposited on a barge.
		Hybrid or Specialty Dredging	Dredges specifically for environmental remediation combine aspects of both mechanical and hydraulic dredges. Examples are the Bonacavor Hydraulic Excavator, AMPHIBEX, Dry Dredge, Crawl Cat Cutter Suction Dredge, and Vic Vac.
	Dry Excavating	Excavator	Conventional backhoe equipment is used to remove sediment which has little water covering it, or sediment that has been dewatered by erecting sheet pile walls and cofferdams.

TABLE 3-6
POTENTIAL TECHNOLOGY TYPES AND PROCESS OPTIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	*Technology type*	*Process Option*	*Description of Process Option*
In Situ treatment	Chemical	*In Situ* oxidation	Injection into sediment and mixing of oxidizing agents such as: permanganate (MnO^{4-}), Fenton's reagent (hydrogen peroxide [H_2O_2], ferrous iron [Fe^{+2}]), Ozone (O_3), and Persulfate ($S_2O_8^{2-}$) to oxidize organic COCs.
		Electrochemical oxidation	A low voltage AC/DC current is applied to sediment using a series of electrodes. The process stimulates mineralization of organic constituents and/or movement of metal constituents to the electrodes.
	Biological	*In Situ* slurry biodegradation	Aerobic, anaerobic, or aerobic/anaerobic sequential degradation of organic COCs by native or introduced microorganisms. Degradation is enhanced by controlling oxygen levels, nutrients, and pH. Slurry treatment would use aerators and/or mixers.
		In Situ aerobic or anaerobic biodegradation	Native populations of COC-degrading microorganisms are enhanced by the addition of (1) more microorganims, (2) nutritious mineral or biological amendments, or (3) a combination of these.
	Physical immobilization	Ground freezing	Freezing is induced by driving pipes through the sediment, circulating a refrigerant liquid through the pipes, and then excavation of the frozen soil.
		Solidification/Stabilization	Injection or mixing of binding agents such as portland cement, lime-kiln dust, gypsum, polymers, or other proprietary agents or methods to alter the chemical or physical characteristics of sediments and make COCs less available for ecological or human exposure.
Ex Situ treatment	Biological	Landfarming/Composting/Biodegradation	Landfarmed sediment is mixed with some of these: nutrients, enzymes, fungi, and, air. Sediment is spread over a treatment area where leachate is collected in a lined bed. Moisture, heat, oxygen, and pH can be managed to enhance biodegradation. Composting: organic amendments such as wood chips, straw, hay, corn cobs, potato waste, or alfalfa are added to enhance bacterial growth and biodegradation.
		Biopiles	Impaired sediment is stockpiled between 3 and 10 feet high. Microbial activity is stimulated with air, nutrients, straw, minerals, or moisture. Air is forced into the stockpiles by perforated pipes.
		Bioslurry Treatment	A slurry is created by mixing water with sediments. The slurry is mixed in a bioreactor to keep solids suspended and microorganisms in contact with COCs. Upon completion, the slurry is dewatered and the treated sediment is removed for disposal.
	Chemical	Acid Extraction	Some constituents adsorb onto the fines fraction of sediment. An extracting chemical, such as hydrochloric acid or sulfuric acid is used to extract constituents by dissolving them in the acid. It is also known as chemical leaching. The solid and liquid phases are then separated, and the solids are transferred to a rinse system, where they are rinsed with water to remove entrained acid and constituents. They are then dewatered and mixed with lime and fertilizer to neutralize any residual acid.
		Solvent Extraction	Solvent extraction separates constituents from sediment, reducing the volume of waste to be treated. Constituents are leached from sediment with organic solvents. Solvents may include kerosene, hexane, methanol, ethanol, isopropanol, propane, and butane. Solvent extraction generates three main product streams: constituents, separated solvent/water, and treated sediment.
		Slurry Oxidation	A slurry is created by mixing water with sediments and oxidizing agents to decompose organics. Oxidizing agents include ozone, hydrogen peroxide and Fenton's reagent. Upon completion, the slurry is dewatered and the treated sediment is removed for disposal.
	Chemical/Physical	Soil Washing	Most constituents bind to finer soil particles (clay and silt) rather than the larger particles (sand and gravel). Physical methods are used to separate the relatively clean larger particles from the finer particles. This process concentrates the COCs bound to the finer particles for further treatment. Sediment is screened to remove oversized particles and then homogenized. The sediment is mixed with a wash solution of water or water enhanced with chemical additives such as leaching agents, surfactants, acids, or chelating agents to help remove organic compounds and heavy metals. Particles are separated by size, concentrating the COCs with the fines.
		Dechlorination	Dechlorination removes chlorine from compounds such as PCBs. A chemical reagent is added to the sediment under alkaline conditions at temperatures of 110-340°C for several hours. The resulting products are less toxic than the original constituents. Vapors are removed from the processor, condensed, and further treated using activated carbon. The treated residue is rinsed to remove reactor by-products and reagent and is then dewatered prior to disposal.

TABLE 3-6
POTENTIAL TECHNOLOGY TYPES AND PROCESS OPTIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	*Technology type*	*Process Option*	*Description of Process Option*
Ex Situ treatment (continued)	Physical	Solar Detoxification	Solar energy degrades organic compounds by direct thermal decomposition or by photochemical reaction. Solar radiation is reflected by mirrors (heliostats) and absorbed by a receiver reaching temperatures of up to 2000°C.
		Solidification/Stabilization	Physical stabilization processes alter the physical character of the sediments to form a solid material, which reduces the accessibility of the constituents to water and entraps the impaired solids within a stable matrix. Binders used to immobilize constituents in sediments include portland cement, pozzolans, bentonite, lime, plaster of paris, thermoplastic resins, and zeolites.
	Thermal	Pyrolysis	Solids are heated in the absence of oxygen. The pyrolysis system consists of a primary combustion chamber, a secondary combustion chamber, and pollution control devices. High temperatures decompose large, complex molecules into simpler ones. The resulting gaseous products can be collected (e.g., on a carbon bed) or destroyed in an afterburner. A solid coke residue of carbon and ash is produced.
		Incineration	Sediments are heated in the presence of oxygen to oxidize organic compounds. Higher temperature incineration (760°C) produces a dense slag or vitrified (glass-like) solid.
		High Pressure Oxidation	A combination of high temperature and pressure are used to break down organic compounds. Temperature ranges from 150°-600°C and pressures range from 2,000-22,300 Mpa.
		Thermal Desorption	Volatile and semivolatile compounds are physically separated from sediments by heating sediments to temperatures of 90 to 540°C. Water, organic compounds, and some volatile metals are vaporized and are then condensed and collected as liquid, captured on activated carbon, and/or destroyed in an afterburner.
		Vitrification	Sediment is treated with high temperature to cause melting and formation of a glass when cooled. Graphite electrodes are inserted into the contaminated sediment and energized with a high electrical resistance heating (more than 1,700°C) to melt sediment into a molten block.
Disposal	On-site or off-site disposal	Landfill/Beneficial use/Confined	Sediments are taken off-site to a landfill, used for a beneficial purpose after treatment, or confined to an isolated area on-site.

TABLE 3-7
CRITERIA AND NUMERICAL SCORING FOR EVALUATION OF REMEDIAL TECHNOLOGIES
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

Score	*Criteria*
	Technical Effectiveness
1	Not effective
2	Slightly Effective or the effectiveness can not be determined
3	Innovative Technology that has potential to be effective based on effectiveness in previous applications
4	High probability of effectiveness and effective in numerous other applications
	Implementability
1	High degree of disruption in the project area and a significant amount of specialized equipment, technical knowledge, and/or permits will be required.
2	Medium degree of disruption in the project area and a moderate amount of specialized equipment, technical knowledge, and/or permits will be required.
3	Minimal degree of disruption in the project area and no specialized equipment, technical knowledge, and/or permits will be required.
4	No disruption in the project area and minimal equipment will be required.
	Cost
1	High
2	Moderate
3	Low
4	No Cost

TABLE 3-8
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	*Remedial Technology Type*	*Process Option*	*Ranking*			*Retained for Further Evaluation?*
			Effectiveness	*Implementability*	*Cost*	
No action	None	Not applicable	1	4	4	Yes
Institutional controls	Non-engineered actions intended to reduce human exposure to sediments	Proprietary controls	2	1	3	No
		Informational devices	2	2	3	No
		Enforcement tools	2	1	3	No
		Site registry	2	2	3	No
	Engineered actions intended to reduce human exposure to sediments	Access restrictions	2	2	3	No
Monitored natural recovery	Chemical/physical transport and degradation	Combined	3	4	3	Yes
	Biological degradation	Metabolism of COCs by microorganisms	3	4	3	Yes
	Physical burial processes	Burial by sedimentation and deposition	3	4	3	Yes
Enhanced natural recovery	Thin-layer placement	Application of a thin layer of clean material	2	2	3	No
	Enhanced thin layer cap	Application of a thin layer of clean material with amendments	2	2	3	No
Containment	*In Situ* capping	Conventional sand cap	4	2	3	Yes
		Conventional sediment or clay cap	4	2	3	Yes
		Armored cap	4	2	3	Yes
		Composite cap	4	2	3	Yes
		Spray cap	4	2	3	No
		Reactive cap	4	2	3	Yes
Removal	Dredging	Hydraulic dredging	4	2	2	Yes
		Mechanical dredging	4	2	2	Yes
		Hybrid or Specialty Dredging	4	2	2	Yes
	Dry Excavating	Excavator	4	2	2	Yes

TABLE 3-8
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	***Remedial Technology Type***	***Process Option***	***Ranking***			***Retained for Further Evaluation?***
			Effectiveness	***Implementability***	***Cost***	
In Situ treatment	Chemical	*In Situ* oxidation	2	1	1	No
		Electrochemical oxidation	2	1	1	No
	Biological	*In Situ* slurry biodegradation	2	1	1	No
		In Situ aerobic or anaerobic biodegradation	2	2	2	No
	Physical immobilization	Ground freezing	1	1	1	No
		Solidification/Stabilization	3	2	2	No
Ex Situ treatment	Biological	Landfarming/Composting/ Biodegradation	3	1	3	No
		Biopiles	3	1	3	No
		Bioslurry Treatment	3	2	2	No
	Chemical	Acid Extraction	3	2	1	No
		Solvent Extraction	3	2	1	No
		Slurry Oxidation	3	2	1	No
	Chemical/Physical	Soil Washing	3	2	1	No
		Dechlorination	3	2	1	No
	Physical	Solar Detoxification	1	1	2	No
		Solidification/Stabilization	3	2	2	No
	Thermal	Pyrolysis	4	2	1	No
		Incineration	4	2	1	No
		High Pressure Oxidation	4	2	1	No
		Thermal Desorption	4	2	1	No
		Vitrification	3	2	1	No
Off-Site Disposal	Dredging/Disposal	Hydraulic dredging/disposal	4	2	3	Yes
		Mechanical dredging/disposal	4	2	3	Yes
		Hybrid or specialty dredging/disposal	4	2	3	Yes
	Excavation/Disposal	Excavation/disposal	4	2	3	Yes

TABLE 3-9
TECHNOLOGIES AND PROCESS OPTIONS RETAINED AFTER SCREENING
STAR LAKE CANAL SUPERFUND SITE
JEFFERSON COUNTY, TEXAS

General Response Action	***Remedial Technology Type***	***Process Option***
No action	None	Not applicable
Monitored natural recovery	Chemical/physical transport and degradation	Combined
	Biological degradation	Metabolism of COCs by microorganisms
	Physical burial processes	Burial by sedimentation and deposition
Containment	*In Situ* capping	Conventional sand cap
		Conventional sediment or clay cap
		Armored cap
		Composite cap
		Reactive cap
Removal/Off-Site Disposal	Dredging/Disposal	Hydraulic dredging / off-site disposal
		Mechanical dredging / off-site disposal
		Hybrid or Specialty Dredging / off-site disposal
	Excavation/Disposal	Excavation / off-site disposal

TABLE 4-1

REMEDIAL ALTERNATIVES

STAR LAKE CANAL SUPERFUND SITE

JEFFERSON COUNTY, TEXAS

JEFFERSON CANAL AOI (Polygons that correspond to sample numbers: JC-2, JC-7, JC-13, JC-18, JC-19)	
1	No Action
2	Containment and 12-inch Removal/Disposal and Backfill: Pipe Containment of JC-7 (extend existing pipes 700 feet and backfill): Excavation with heavy equipment of remainder of Jefferson Canal polygons.
3	12-inch Removal/Disposal and Backfill: Excavation and backfill to existing grade: Do not modify the existing channel hydraulic characteristics
JEFFERSON CANAL SPOIL PILE AOI (Polygons that correspond to sample numbers: JCSP- 1 through JCSP-25, inclusive, and JC-8, JC-9, JC-10, and JC-11)	
1	No Action
2a	Containment - without excavation: Composite Cap (12-inch clay and 12-inch topsoil)
2b	Partial Containment - without excavation: Composite Cap (12-inch clay and 12-inch topsoil)
3a	Partial 12-inch Removal/Disposal and Containment: Composite Cap (12-inches clay and 12-inches topsoil)
3b	Partial 12-inch Removal/Disposal and Partial Containment: Composite Cap (12-inches clay and 12-inches topsoil)
FORMER STAR LAKE AOI (Polygons that correspond to sample numbers: SL-6, SL-7, SL-9, SL-10)	
1	No Action
2	12-inch Removal/Disposal and Containment: 12-inch Impermeable Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
3	12-inch Removal/Disposal and Containment: 12-inch soil cap. Do not modify the hydraulic capacity or the soil/water topography.
STAR LAKE CANAL AOI (Polygons that correspond to sample numbers: SLC-6, SLC-11)	
1	No Action
2	12-inch Removal/Disposal and Containment: 12-inch Impermeable Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
3	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
GULF STATES UTILITY CANAL AOI (Polygons that correspond to sample number: GSUC-7)	
1	No Action
2	Containment - without excavation: 12-inch Composite Cap
3	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
4	12-inch Removal/Disposal
MOLASSES BAYOU WATERWAY AOI (Polygons that correspond to sample numbers: MB-10, MB-14, MB-18/MB-18R, MB-21, MB-24, MB-49, MB-52, MB-54, MB-60, MB-61)	
1	No Action
2	Monitored Natural Recovery (10-year duration of measurement)
3	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
MOLASSES BAYOU WETLAND AOI (Polygons that correspond to sample numbers: MB-26, MB-51, MB-56, MB-58, MB-59, MB-62, MB-63)	
1	No Action
2	Monitored Natural Recovery (10-year duration of measurement)
3	Containment - without excavation: 12-inch Composite Cap
4	12-inch Removal/Disposal and Containment: 12-inch Armored (protective) Cap (minimizes erosion). Do not modify the hydraulic capacity or the soil/water topography.
5	12-inch Removal/Disposal

Note:

Refer to Appendix A to view pipelines at or near every Area of Investigation (AOI).